The Evaluation of Butterfly Pea (Clitoria ternatea L.) Genotypes for their Production Potentials under varying Environments

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BY

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CERTIFICATE

It is certified that this thesis entitled **The evaluation of Butterfly Pea (*Clitoria ternatea* L.) genotypes for their production potential under varying environments** is an original piece of research work done by Shri U.P. Singh, M.Sc. (Botany), Sr. Scientist IGFRI, Jhansi under my supervision and guidance for the degree of ***Doctor Of Philosophy*** (Botany), Bundelkhand University, Jhansi.

I, further certify that;

- The thesis has been duly completed
- It embodies the original work of candidate himself
- The thesis fulfils the requirements for the Ph.D. degree of the Bundelkhand University
- It is upto the required standard both in respect of its contents and literary presentation for being referred to the examiners.
- The candidate has worked under me for the required period (200 days) at National Research Centre for Agroforestry, Jhansi.

(R. Deb Roy)

DECLARATION

I hereby declare that the thesis entitled **The evaluation of Butterfly pea (*Clitoria ternatea* L.) genotypes for their production potentials in varying environments** being submitted for the degree of **Doctor of Philosophy** in Botany, Bundelkhand University, Jhansi (U P) is an original piece of research work done by me under the supervision of Dr. R. Deb Roy Ex-Director, NRCAF, Jhansi and to the best of my knowledge, any part or whole of this thesis has not been submitted for a degree or any other qualification of any university or examining body in India/ elsewhere.

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INTRODUCTION

INTRODUCTION

The availability of nutritious fodder from arable and non-arable areas is vital to increasing animal productivity in this country. The major source of cattle feed is through pasture crops and the native grasslands besides other sources such as the food crop residues, cultivated fodder crops. The grasslands in this country are located on badly eroded soils which are very poor in fertility and moisture retention. The present day grasslands are in a highly degraded state providing low biomass of poor nutritional quality. These native grasslands are dominated by different grass species namely *Sehima nervosum, Dichanthium annulatum, Cenchrus spp., Heteropogon contortus, Phragmites spp., Sachharum Spp, Themeda spp., Iseilema spp.* etc. (Dabadghao and Shankarnarayan, 1973). These indigenous grasses are low in protein content and poor in digestibility. Unlike grasses, which dominate productivity, the protein rich legume species are represented in very low number and their contribution to the overall productivity of the grassland is also meagre. Some of the frequently occurring legume species in the grassland are *Atylosia scarabaeoides, Alysicarpus rugosus, A. vaginalis, Zornia diphylla* etc.(Kanodia, 1984). The natural grasslands are localised in the tribal belts of Madhya Pradesh, Maharastra, Gujrat, Rajasthan and Uttar Pradesh.These areas are traditionally being used by tribal communities for their day to day requirement of fuel, fodder and animal grazing (Jodha, 1985; Agrawal, 1988).

The widespread malnutrition of the grazing animals in India is mainly attributed to protein hunger of the animals. The high cost of chemical fertilizers for improving forage production and quality puts them beyond the reach of the poor farming communities. Furthermore a wide scale use of chemical fertilizer in the native grassland is also environmentally hazardous and, therefore, not recommended. The cheapest way to improve forage quality, world over, has been through increasing the occurrence of productive forage legumes in the native grassland. Grass-legume pastures are known to improve the herbage quality (Trinbath, 1974; Whana and Millar, 1978; Hazra, 1988) and soil status in term of organic carbon , available nitrogen and phosphorous (Singh, 1988; Hazra and Behari, 1993). Besides these the legumes also help in changing soil structure and increasing soil binding capacity as well as checking weed infestation in grasses and cereals (Schofield, 1945; King *et al.* 1965).Introduction of legume species as an intercrop with grasses has been recommended by many workers (Donald, 1963; Shankarnarayan *et al.* 1975; Velayudhan *at el,* 1977 & 1979; Chauhan and Faroda, 1979; Kanodia, 1984; Dwivedi *et al.* 1991; Hazra, 1995).

Over the past few decades a number of productive pasture legumes such as *Macroptelium, Stylosanthes, Centrocema, Desmodium, Dolichos, Clitoria* etc. have been widely exploited for the improvement of native pasture in the arid and semi-arid areas of the world. For the degraded grasslands the best land use system is grass legume intercropping for reducing soil water loss and for improving the physico-chemical properties of the soil (Hazra, 1988).

Amongst the indigenous legumes, *Clitoria ternatea*, a productive pasture legume, has shown wide range of adaptability and persistency in arid to warm-humid areas of the country (Whyte *et al.*, 1969; Chakravarty, 1970; Singh and Singh, 1988; Singh and Gupta, 1991). Introduction of *Clitoria* in *Cenchrus* based pasture significantly increased total nutrient out turn as compared to *Cenchrus* alone (Velayudhan *et al.*, 1976).

Clitoria ternatea Linn. commonly known as Butterfly pea or / Aparajita is widely distributed in the warm humid tropics of Africa, Asia and Central America. It is a highly persistent long term perennial legume adapted to medium to high rainfall situations (Crowder, 1974; Crowther and Staple, 1978). Considerable wealth of information has been collected by Australian scientists on the genetic diversity, adaptability and production potentiality of this legume as sole or mix crop with pasture grasses (Cameron and Mullay, 1969 ; Reid and Sinclair, 1980; Fantz, 1991; Hall, 1985 & 1992). Wide genetic diversity in the different regional accessions of *Clitoria* has also been observed in the Indian material (Singh and Singh, 1988) and in the American and old world materials (Reid and Sinclair, 1980). Direct selection of high yielding strains from germplasm has resulted in the release of a composite variety namely 'Milgarra' in Australia (Hall, 1992).

Clitoria seed is characterised by hard seededness which accounts for dormancy over long periods of storage. Considerable variation exists for flower colour, seed shape, size and seed coat pigmentation. Prolonged periods of storage helps in overcoming dormancy to some extent (Chatterji, 1966; Mullick and Chatterji, 1967; Hall, 1992). Seed scarification through treatments such as hot water, concentrated sulphuric acid and potassium hydroxide have been recommended to overcome the problem of hard seededness and to achieve adequate germinability of seed (Mullick and Chatterji, 1967; Bogdon, 1977).

Although *Clitoria* is indigenous to India but it remains under exploited so far . High production potential of *Clitoria* has been reported for Rajasthan (Chakravarty, 1970) and Uttar-Pradesh (Singh and Singh, 1988; Singh and Gupta 1991). *Clitoria* is endowed with excellent forage quality as its crude protein content varies from 13 to 25 % on dry matter basis and has more than 70 % digestibility (Katiyar *et al.* 1970; Upadhyay and Pachauri, 1983; Adjei and Fianu, 1985).

Clitoria being a creeper is a better competitor than the companion grasses in intercepting photosynthetic energy, but is slow growing at the initial stages when it is subjected to intense grass competition for moisture and nutrients. Early growth vigour is important for successful introduction of the legume in the grasslands. Studies have revealed considerable variation in the relative growth rate (RGR) of the different cultivars at the different stages of plant growth (Singh and Singh, 1988).

Despite the paramount importance of *Clitoria ternatea* for improving the productivity of the native pastures in India, the research efforts made so far on the aspects of its successful introduction in the different types of grasslands are scanty and scattered. *Clitoria* is a climber as well and forms a thick canopy over the bushes to provide nutritious feed for the browsing animals. A silvi-pasture system (involving *Clitoria,* grass and subabul) offers scope of creating protein rich pasture for round the year use.

In the present study a sizable collection of *Clitoria ternatea* genotypes have been made from different parts of the country for studying the genetic diversity, classifying the materials and identifying desirable types. Since establishment of a legume pasture depends on proper plant stand which in turn depends on seed quality, detailed studies on germination behaviour of the polymorphic seeds under different environments were undertaken. The present study addresses to the problem of *Clitoria* introduction in different types of native grasses such as *Cenchrus ciliaris, Chrysopogon fulvus and Heteropogon contortus* and the tree legume *Leucaena leucocephala* and the associative response of different combination of grass-legume pasture.

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REVIEW OF LITERATURE

The Leguminosae (Fabaceae) comprises of about 700 genera and 18,000 species which includes herbaceous plants, shrubs, trees and climbers. The Leguminoseae are divided into three tribes viz. Caesalpinoideae, Mimosoideae and Papilionoideae. The Papilinoideae (also described as Fabaceae, Faboideae, Lotoideae or Papilionaeae) is the most useful tribe and provides a very large number of important crop plants to mankind. The genus *Clitoria* comprises of about 60 species distributed mostly in humid and sub-humid tropics and lowlands of old world (Bogdan, 1977; Fantz, 1991). The genus belongs to Papilionaceae and is characterised by multicoloured, resupinate, papilionaceous flowers with infundibular and persistent bracteoles, stalked ovary with geneculate and bared style (Fantz, 1991). The growth habit varies from small herb to creeper, liana (true creeper), under shrub and trees (Table 1). The genus is important as it has very high medicinal, ornamental and forage value. Some of the species such as *Clitoria marina, C. fulcata, C. fairchildiana* have fragrant mauve coloured flowers of ornamental importance (Allen and Allen, 1981 ; Arora and Chandel, 1972; Arora and Singh, 1987).

The *Clitoria ternatea* Linn. is one of the most important species of genus *Clitoria* which has manifold uses such as ornamental / medicinal and forage value etc. Basically this species is native of tropical America (Bermudez *et al.* 1968) but later became more acclimatized in the humid and sub-humid tropics of Africa, Asia and Central America both naturally as well as an escape from cultivation (Fantz, 1977). Its centre of maximum diversity is located in central and south western India (Whyte, 1969; Mehra and Magoon, 1974; Arora and Singh, 1987). Wide spread use of this species is mentioned in several ancient books of Ayurveda such as; Charak Sanhita, Vag Bhatt, Brind Manav, Shodal and Sarangdhara Sanhita etc. (Singh and Gupta, 1991).

The genus was first named by Breyne (1678) as 'FLOS CLITORIDIS TERNATNSIBUS'. The Portuges Vernacular name 'FULA ERIQUA' was derived from the flowers (Rumpf, 1747), later on the Spanish work 'CONCHITA' found in vernacular names 'BEJIEP DE CONCHITA' or 'Conchita azal' and Conchita blauca (*Clitoria ternatea*) which has sexual connotation in reference to its medicinal use in child birth as a stimulant (Gooch and Paudes, 1978; Garcio–Pelayo and Graes, 1979; Dobois Charlier, 1986). Many other synonymic names are also available in the literature such as Butterfly pea (in English), Blue pea or Kordofan pea (Sudan), Cunha (Brazil) and in Philippines it is named as Pokindong (Fantz, 1977; Hall, 1985). Similarly in different Indian languages, the species is named as Titali matar (Hindi)

Table 1 : Important *Clitoria* species at a glance.

Habit	Flowers size and colour
A. Creeper or vine	
Clitoria ternatea	Blue, blue violet or white, 4-6 cm
Clitoria falcata	White, 4-6 cm
Clitoria heterophylla	Blue, 2.5-3 cm
Clitoria javanica	White, 3-4 cm
B. Liana or climbing type	
Clitoria arborescens	Violet, 4-6 cm
Clitoria javitensis	Pink or rose colour, 6.5-8 cm
Clitoria lasciva	Blue, 5.5-6.3 cm
C. Herb	
Clitoria marina	Lilaceous or lily white, 4-6 cm
D. Under shrub	
Clitoria lanifolia	White, 4-5 cm
E. Tree	
Clitoria glaberrima	White, 3-3.5 cm
Clitoria fairchildiana (*C. recemosa*)	Violaceous, 4-6 cm
Clitoria dendrina	Dark purple, 3-4 cm
Clitoria brachystegia	Violaceous, 4-6 cm

Aparajita (Sanskrit), Vishnu kanta (Bengali), Sankhu Pushpum (Tamil), Gokarna (flowers shape like that of cows ears) in Gujrati. Other synonyms are Kalijar, Kakanam, Koyal etc. (Singh and Gupta, 1991).

Butterfly pea is cytologically diploid with chromosome number $2n = 16$ (Darlington and Whylie, 1955). It is self-pollinated crop but 5 to 10% out-crossing has also been reported and segregating genotypes have been identified within natural population (Crowder, 1974). This species has been widely researched for its medicinal use by many authorities (Sanyal and Ghose, 1934; Burkill, 1935; Chopra *et al.* 1949 & 1958; Quisumbing, 1951; Hocking, 1955; Gardener and Benette, 1956; Dastur, 1962; Jayaweera, 1981: Kirtikar and Basu, 1918; Mortan, 1983; Ambasta, 1986; Duke, 1986; Abbiw, 1990). Different parts of the plant are being used in various disorders of human being as well as in livestock (Table 2). As per the information available it has desirable quality fodder with 13-25 % crude protein on dry matter basis and more than 70 % digestibility (Katiyar *et al.*, 1970; Upadhyay and Pachauri, 1983; Adjei and Fianu, 1985; Singh and Gupta, 1991). A compound named as 'Aparajitin' ($C_{26}H_{50}O_2$) was reported by Tiwari and Gupta (1959) from alcoholic extract of dried leaves and determined chemical content named as; 'O-Lactose of 2-inethyle-4-hydroxy-n Penta casonoic acid'. Aiyar *et al.* (1973) isolated beta-sitasterol and Aparajitin from leaves and also reported Kaempferol-3 rhmnoglucoside and P-hydroxycinnamic from seeds. The testa and cotyledons are full of starch (Nadkarni, 1927). The seeds of *C. ternatea* have fixed oils, tannin and bitter resinous compounds (Allen and Allen, 1981; Ambasta, 1986). An yellow oil 'Gamma sitesterol' was reported by Sinha, (1960 a). Hexacosanol hetasitosterol and an anthoxanthin glucosides were isolated by Gupta and Lal (1968).

The divergence in relation to breeding system has indicated that the morphological parameters had the largest contribution to genetic diversity in various crop species (Murty and Arunchalam, 1966) and similarly D^2 analysis and other advance methods in biometric research were successfully used for the grouping and the classification of large number of accessions in many crops like *Brassica, Sorghum, Avena* etc. (Rao, 1952; Murty and Quadri, 1966; Arunachalam and Ram, 1967; Rana and Murty, 1971; Mehra *et al.* 1970 ; Nair and Gupta, 1977).

Metroglyph and Index scoring method (Anderson , 1957) have been used to study the variation pattern in various crops. Many workers followed this method for the classification of genetic material of several crops such as; in sorghum (Mehra *et al.* 1970), maize (Mukherji *et al.* 1971) and in lablab/field bean (Singh and Singh, 1992).

First catalogue on world collection of sorghum was developed by Murty (1967) which identified several resistant lines to specific disease and pests. Later several catalogues

Table 2: Medicinal properties of *Clitoria ternatea* linn.

Disorder/quality	Part used	Reference
I. Infection due to sting /or animal bite		
Scorpion sting	Roots	Chopra *et al.* 1949 & 1958
Snake bite	Roots	Chopra *et al.* 1949 & 1958
Tapeworm (Antihelminthic)	Seeds	Dastur, 1962; Quisumbing, 1951
II. Gastro-Intestinal		
Antidysentery	Flowers	Morton, 1983
Apertent (laxative medicine)	Roots	Quisumbing, 1951; Jayaweera, 1981; Duke, 1986
Cathertic	Roots	Chopra *et al.* 1949 & 1958 Dastur, 1962; Jayaweera, 1981; Ambasta, 1986
Laxative	Roots	Hocking, 1955; Jayaweera, 1981
	Root bark	Chopra *et al.* 1958
	Seeds	Dastur, 1962; Mortan, 1983; Abbiw, 1990
Purgative	Roots	Chopra *et al.* 1949; Duke, 1986
Ulcers	Leaf juice/ leaf fusion	Dastur, 1962

(Contd..2)

(Contd..2)

(Contd..2)

1	2	3
III. Urogenital system		
Antiperiodic	Roots Leaves	Hocking, 1955 Hocking, 1955
Emmenagogue	Flowers fusion Roots Roots fusion	Morton, 1983 Quisumbing, 1951 Morton, 1983
Gonorrhea	Leaf Juice Root bark	Chopra *et al.* 1958; Dastur, 1962
IV. Inflammation		
Cystitis	Seeds	Duke, 1986
Eczema	Leaf juice	Chopra *et al.* 1958
Eye	Flower juice	Burkill, 1935
Impetigo	Leaf juice	Chopra *et al.* 1958
Prurigo	Leaf juice	Chopra *et al.* 1958
Skin eruption	Leaf fusion	Chopra *et al.* 1949; Quisumbing, 1951
V. Pulmonary system		
Bronchitis (Phlegm removal)	Roots	Dastur, 1962; Quisumbing, 1951
Hepatic fever	Leaves	Quisumbing, 1951
Refrigerant	Seeds	Duke, 1986

(Contd..2)

Contd...2

1	2	3
VI. Vomative		
Emetic	Leaves Roots	Hocking, 1955; Gardner and Benette, 1956
Vomative	Roots	Hocking, 1955; Abbiw, 1990; Dastur,1962
VII. Poison's antidote		
	Seeds	Duke, 1986
VIII. Fluid accumulation		
Abdominal viscera	Roots Seeds	Dastur, 1962 Jayaweera, 1981
Anasarca	Roots	Jayaweera, 1981
Ascites	Roots	Kirtikar and Basu, 1918; Jayaweera, 1981
Biliousness	Roots	Jayaweera, 1981
Diuretic	Roots	Sanyal and Ghose, 1934; Chopra *et al.* 1958; Hocking, 1955; Dastur, 1962; Quisumbing, 1951; Jayaweera, 1981; Ambasta, 1986
Demulcent	Root bark	Quisumbing, 1951; Dastur, 1962; Jayaweera, 1981

and descriptors have been developed for many crops such as; Cluster bean (Dabas *et al.* 1981; Chopra *et al.* 1983; Patil *et al.* 1983), Metha (Shukla and Sharma, 1978; Kohli, 1981), Mothbean (Chopra *et al,* 1980 & 1981), Cowpea (Mehra *et al.*1969; Kohli *et al,*1971; Pant *et al.* 1982) and Field peas (Singh *et al.*1974). Some other forage crops have also been catalogued such as: *Cenchrus ciliaris* (Patil and Singh, 1960; Chakravorty *et al.* 1970; Yadav *et al.* 1974; Yadav.1981), forage sorghum (Mathur *et al.* 1991), oats (Mehra *et al.*1970; Mehra,1978) while Gupta *et al.*(1984) also catalogued many forage crops.

Butterfly pea is being cultivated in many parts of the world including India but escaped due research attention (Chakravorty, 1970; Crowder, 1974; Hall, 1985; Reid and Sinclair, 1980; Adjei and Fianu, 1985; Singh and Singh 1988; Singh and Gupta, 1991). Further in the developmental series Anning *et al.* (1981) documented 121 diverse germplasm lines at three sites of Queensland and evaluated them for adaptability to different agro-ecological tracts. Reid and Sinclair (1980) evaluated 58 accessions of old and new world tropics. Phenotypic variation among fodder yielding attributes on 56 germplasm lines was worked out by Singh and Singh (1988). Wide scale cultivation of butterfly pea as a protein rich forage legume for rainfed areas was also reported (Singh and Gupta, 1991; Singh and Gupta ,1995) and authors also identified eight promising genotypes for their outstanding forage productivity. Hall (1992) developed an outstanding variety for North Queensland (Australia) named as 'Milgarra'. It is a composite line evolved by combining selected introduction and neutralized lines over three generations.

Clitoria has fair adaptability in sandy and sandy loam soils of arid and semi-arid regions of India (Chakravarty, 1970; Singh and Singh, 1988; Singh and Gupta, 1991) and is a highly persistant species (persists upto 14 years) in North-West Queensland in clay soils (Hall, 1985) and is reported as most persistent species after *Stylosanthes* and *Macroptelium* (Anning, *et al.* 1981; Reid and Sinclair, 1980). Continuous grazing adversely affected the persistency but it survived very well under rational grazing . In Africa it grows very well in inundated grasslands of clay to black clay soils (Parvery, 1967; Blunt and Chapman, 1978; Hall *et al.* 1985). It is successfully cultivated in area with 500 mm rainfall but parellelly it also exhibits outstanding performance in areas with 1000-1500 mm precipitation (Van Ransberg, 1967; Cameron *et al.* 1984). It is drought tolerant species growing luxuriantly in irrigated situation but fails to survive under water logged conditions.

Seed morphology and germination behaviour

The germination behaviour in leguminous seeds has been of much interest as this group has got varied seeds in shape, size and colour. Hard seededness and dormancy in seeds also affects the germination in various species (Hamely, 1932; Toole *et al.* 1956; Billings, 1957;

Miller, 1967). Hamely, (1932) used the impaction technique for the first time to break the dormancy which was followed by many other researchers (Watson, 1948; Toole *et al.* 1956; Chatterji, 1966; Mayer and Poljokoff-Mayber, 1982). The change in permeability or rupturing of strophiolar cleft or plug has been successfully demonstrated by Barton and Crocker (1948) in *Melilotus alba, Trigonella arabica, Crotolaria aegyptiaca* and *Cassia artimisioides.* Scarification, cutting and piering techniques were demonstrated by Rao *et al.* (1985) in small legumes like *Atylosia* species for breaking dormancy. Paroda *et al.*(1985) studied the germination behaviour in Pigeon pea (*Cajanus cajan*) where the hard seededness varied from 5% to more than 70%.

Literature indicates that *C.ternatea* has polymorphic seeds (varied in shape, size and colour), hard seededness and dormancy (Chatterji, 1966; Mullick and Chatterji, 1967; Singh and Singh, 1988; Hall, 1992) but when stored for 180 days or more, the seed coat impermeability may get broken and germination could be obtained in 20-30 % seeds (Mullick and Chatterji, 1967 ; Hall, 1992). Use of chemicals such as concentrated sulphuric acid, potassium hydroxide and hot water treatment may also promote the germination percentage. Besides germination, these treatments also encouraged the early plant growth in butterfly pea (Bogdon, 1977; Hall, 1992).

Genotypic stability

For any crop improvement programme, it is essential to examine the identified genotypes for their stability parameters. To study the stability Yates and Cochran (1938) developed the technique for analysis of genotypic *X* environmental interaction, which was modified by Finlay and Wilkinson, (1963). They used this method for screening of the barley varieties. The technique evolved the partitioning of gene *X* environment variance components into linear and non-linear portions. The technique was widely adopted by the statisticians and biometrical geneticists for assessing the stability of genotypes over a range of environments (Eberhart and Russel, 1968; Perkins and Jinks, 1968; Freeman and Perkins, 1971; Fripp and Cateu, 1971; Tai, 1971 Nor and Cady, 1979; Shukla, 1983).

The formal analysis for genotypes *X* environment interaction as derived by Yates and Cochran (1938); Finlay and Wilkinson (1965); Perkins and Jinks, (1968). The approach is commonly known as 'Joint regression analysis'. It provides measures of stability (I) regression coefficient (bi) and (II) deviation from regression mean square (S^2 di). The joint regression approach as outlined by Eberhart and Russell, (1966) slightly differs from the earlier ones. In this case the sum of square for environment and gene *X* environment interaction are added to get the within genotypes sum of squares which is partitioned into linear component of gene *X* environment between environments with 1 df. A linear component of gene *X* environment

interaction with (t-1) df. and deviation from linear regression (s-2) df. Eberhart and Russel (1966) emphasised the need of considering both linear (bi) and non-linear (S^2di) component of genotype X environment interaction in the judging of stability of the cultivars. Later Breese (1969); Samual *et al.* (1970); Paroda and Hays (1979); Saini *et al.* (1986); Jatasra and Paroda (1979); Dangi *et al.* 1994; Henary (1995); Singh *et al.* (1995); Lodhi and Sangwan, 1996 advocated that the linear regression could simply be regarded as a measure of response of particular genotype which in fact depend largely on the number of genotypes. The deviation around the regression (S^2di) was considered a better measure for stability. The genotype with a lowest standard deviation being the most stable and vice-versa. On the basis of stability model many authors examined a number of crops for various parameters like GFY in sorghum (Grewal *et al.*, 1987); seed yield in fenu greek (Saini *et al.* 1986); dry matter yield of cowpea (Singh and Hazra, 1987); fodder yielding attributes of lablab (field) bean (Shukla *et al.* 1993); dry matter yield in white anjan grass (Shukla *et al.* 1995) and phenotypic stability in guinea grass (Singh *et al.* 1995).

Relative growth rate (RGR)

The relative growth rate (RGR) is an index of the plants potential to accumulate dry matter over a given period of time. Relative growth rate highly influenced by assimilation of photosynthate in the assimilatory tissues in the plant over a time period (Fitter and Hury, 1981; Yadav and Singh, 1984; Singh and Singh, 1988). In tree species net assimilation rate was observed to be highly positive in relation to RGR (Chakravarti, 1993). Dutta, (1995) during the study of growth dynamics found that in early growth of the plants a maximum relative growth rate was recorded when the photosynthesis was most active. With the advancement of plant age or in summer situations due to leaf fall/mutual shading of high number of young leaves negative trend in NAR (net assimilation rate) resulted the decline in relative growth rate (De Muakadell, 1954; Chakravarti, 1993). It has been assumed that a greater proportion of respiratory losses from non-photosynthetic tissue may prevail the situation (Leopold and Kriedemann, 1975). The canopy structure and display would most likely offer a favourable situation for weight gain (Hedman and Binkley, 1988).

Compatibility of legumes with grasses

High cost of nitrogenous fertilizer poses a great problem for forage production in our country and advantage of mixed system over the monoculture have been realized. Further, the intercropping system of legume+grass is observed to be advantageous for yield and quality aspect (Frey and Maldonado 1967 and Donald 1963). Legumes are known to stimulate the productivity of non-leguminous species (Eaglesham *et al.* 1982; Pandey and Pendleton, 1986)

and the degree of nitrogen transfer may differ for different species/varieties of legumes (Minchin, 1978; Patil, 1980).

The introduction of the pasture legumes viz. *Macroptelium atropurpureum, Clitoria ternatea* and *Stylosanthes humilis* in the base pasture of *Cenchrus-Sehima-Heteropogon* maximum forage production was recorded in *C. ciliaris* + *C. ternatea* mixture (Velayudhan *et al.* 1976) followed by other combinations of grasses /legumes (Velayudhan *et al.* 1977 & 1979). Similarly a considerable increase in dry matter and protein yield per unit area was observed when *Chrysopogon fulvus* was intercropped with *Stylosanthes scabra* (Dwivedi *et al.* 1985) and 190 % more crude protein was recorded in *Dichanthium annulatum* when it was grown with *Stylosanthes hamata* (Rai, 1984). In the arid and semi-arid regions the introduction of various range legumes viz. *Stylosanthes hamata, S. scabra, Lablab purpureus*, etc. in the *Dichanthium annulatum, Sehima nervosum, Cenchrus ciliaris, C. setigerus* and *Lasiurus sindicus* pasture increased the over all biomass production in respect of dry matter and crude protein yield (Dauley *et al.* 1968; Chauhan and Faroda, 1979; Kanodia and Dwivedi,1982; Harsh and Mauria, 1985). Similarly in sub-humid conditions a significant advantage was also recorded in *Pennisetum pedicellatum, Chloris gayana* and *Setaria sphecelata* intercropped with *Stylosanthes guanensis* and *S. hamata* (Prasad 1985; Prasad and Singh, 1988). The total nitrogen and organic components also increased in the soil due to the intercropping cereal grasses with various legumes in addition to increase in biomass production (Paul *et al.* 1981; Singh and Singh, 1985; Rai, 1987 & 1988; Dwivedi *et al.* 1988; Hazra and Behari, 1993).

The grass+legume intercropping system is the best land use system in degraded lands for reducing the soil/water loss and improving the soil physico-chemical properties (Hazra, 1995). When grasses such as; *Setaria sphecelata, Panicum maximum* and *Chrysopogon fulvus* were grown with legume component (siratro and stylo etc.), a significant increase in seed production was observed in grasses comparable to an equivalent dose of 20-30 kg N/h (Dwivedi *et al.* 1988).

Besides these, considerable literature is available on cultivation of three species combination when the pasture legume/grasses were inter-cropped with tree component (silvipastoral system) and are mainly confined to biomass production specially for pasture components (Deb Roy *et al.* 1980 & 1982; Deb Roy and Pathak, 1983; Deb Roy, 1988 & 1991; Deb Roy *et al.* 1980) Encouraging results have been reported by these workers in forage production in *Cenchrus* + *Stylosanthes* pasture grown with *Acacia tortilis* and *Leucaena leucocephala*. The appraisal and better utilization of silvipastoral system has also been discussed by Gill and Deb Roy (1992) which may provide sufficient forage production particularly in lean periods. It is possible to manage twelve sheeps or goats /h for many years (Anon, 1990).

MATERIALS AND METHODS

(1) Genetic diversity

Ninety two diverse genotypes of Butterfly pea (*Clitoria ternatea*) were collected from different agro-climatic situations of tropical, sub-tropical and warm humid regions of India (Table 4 and Fig. 1). These genotypes were properly accessioned and evaluated during the year 1989 to 1992. The experimental work for the present studies was carried out on five main areas of research, namely; gene pool collection and evaluation, germination behaviour of polymorphic seed, genotypic stability, relative growth rate and compatibility of *Clitoria ternatea* with different pasture grasses. All the field experiments were undertaken at Central Research Farm of National Research Centre for Agroforestry (IGFRI Campus), Jhansi. The research farm is situated at 25° - 27' North, 78° - 35' east; 271 m above the sea level and falls in semi-arid plateau hills of **Bundelkhand** having mean annual rainfall 890 (mm) ranging from 670-1160 (mm). The average values of field capacity, wilting point and bulk density of these soils are 12 %, 46 % and 1.45 %, respectively. The soil is neutral in reaction, poor in nitrogen and organic content but rich in potassium (Dohre, 1981).

The experiment was laid out in randomized block design in sandy loam soils. The seeds of all the germplasm lines were sown in first week of July,1989 in 3 m long rows spaced at 0.5 m and 10-15 cm distance between plant to plant respectively. Each plot had three lines and replicated thrice. The experiment was maintained under rainfed conditions for three consecutive years.

Data recording

The observations on various morphological, growth and fodder yielding attributes were recorded at 50 % flowering stage on three randomly selected plants from each plot.These were cut at 10 cm above the ground level for recording the data on fodder yielding attributes.

Days to 50% flowering

On the basis of visual observations, number of days to flower initiation stage was recorded. Number of days were counted from the date of sowing to the flowering initiation in 50 % plant population of entire plot.

Plant height (cm)

Height of the plant was measured in (cm) from the ground base to the apex of the main shoot.

Branch number

Total number of branches on main shoot were recorded from first to the last node.

Secondary branch number

Number of branch sprouts from all the branches were counted.

Branch length (cm)

Length of best developed branch was measured from the place of origin on main shoot (node) to the apex of branch.

Number of leaves/plant

A count of total number of leaves (complete compound leaf with all three foliates) was taken for entire plant.

Green forage yield/plant (g)

Total above ground green biomass in (g) of the plant (both leaf+stem) was weighed just after the cutting.

Dry matter yield/plant (g)

For dry matter yield entire plant samples (green biomass) was put in oven at 60-70°C for more than 40 hours and dried biomass was weighed in (g).

Leaf-stem ratio

Leaf-stem ratio was worked out by dividing leaf dry weight by stem dry weight.

Estimation of crude protein content

Estimation of crude protein content was done as per the method suggested in

A.O.A.C.(1990). For .this, 0.5 g oven dried and grounded sample (including both leaf and stem) was taken and 01 (g) catalyst (mixture $CuSO_4$ and K_2SO_4 in a ratio of 1:5) was added to it. Digestion was done with 10 ml concentrated H_2SO_4 for 2-3 hour till it becomes transparent. Volume was made upto 50 ml in volumetric flask by adding distilled water. 10 ml solution from this flask was taken and distilled in micro Kjeldahl distillation apparatus with 40 % NaOH. Released ammonia was collected in beaker containing 02% boric acid mixed with indicator. The colour of indicator changed from red to blue and released ammonia gas which was absorbed by boric acid. Then Ammonium borate was titrated with standard solution of sulphuric acid and finally 'N' percentage was calculated as;

01 ml of N/100 H_2SO_4 = 0.0014 g N

Crude protein (%) = (%) N x 6.25

Analysis of variance

Statistical analysis was carried out using mean values of various forage yielding attributes following standard statistical procedures with the help of computer software. The significance of variance was tested by 'F' value. Coefficients of variation were calculated for morphological and fodder yielding attributes.

Classification and cataloguing of germplasm

For the classification and cataloguing of germplasm score index method was followed as proposed by Anderson (1957) and accordingly, each parameter was divided into three scoring groups;

I. Low

II. Medium

III. High

These groups were denoted by numerical values '0' '1' and '2' respectively. For score index following parameters were taken viz: days to flowering, plant height (cm), branch number, secondary branch number, branch length (cm), number of leaves/plant,green fodder yield/ plant (g), dry matter yield/plant (g), leaf-stem ratio and crude protein content (%). For each character score ranged between 0-2 and accordingly maximum score by any genotype could be 20. The entire germplasm was grouped and classified.

(2) Factors influencing the germination of *Clitoria* seeds

Seeds of eight promising genotypes showing polymorphic seed coat colour with dark grey dotted testa (ILCT-213 & ILCT 215), bluish grey dotted (ILCT-221 & ILCT 249), brown

colour (ILCT 261 & ILCT 269) and with dark black seeds (ILCT-272 & ILCT 278) were collected during March/April. Collected seeds were stored in separate glass bottles at room temperature for more than 180 days in view of the dormancy reported in this species (Mullick and Chatterji, 1966 and Hall, 1992). The viability of seeds was tested with 2, 3, 5 - Tri-phenyl tetrazolium chloride (235-TTC salt). The seeds were pre-soaked in water for 24 hr., then bisected and embryo containing portion of seed was put in 01% solution TTC for 8 hr. at 30°c. After washing the seeds developed red colour stain which indicated the viability of seeds and almost all the seeds (more than 90%) were found viable. Four different sets of experiments were laid out as mentioned below :

(I) Effect of sowing depths (cm)

The seeds of eight genotypes of butterfly pea were sown in earthen pots at 2 cm, 4 cm, 6 cm and 8 cm depths. Each pot was filled with normal field soil having 0.61, 0.32, 0.18 and 0.53% organic content, nitrogen, P_2O_5 and K_2O respectively with 7.4 pH. Fifteen seeds were sown in every pot. Each treatment was replicated thrice and uniform environmental condition were provided to all the treatments and replicates.

(II) Effect of soil types

The seeds of each genotype were sown at 4 cm sowing depth in earthen pots. These pots were filled with different soils and soil combinations viz.

i) red soil ii) black soil iii) organic soil and iv) mixed soil (mixture of all soil types in equal proportion).

Nutrient status of soils and their combinations;

Soil type	Organic matter	Nitrogen	P_2O_5	K_2O
Red soil	0.59	0.32	0.15	0.51
Black soil	0.78	0.45	0.20	0.50
Organic soil	6.20	0.60	0.27	0.82
Mixed soil	1.25	0.57	0.25	0.62

Fifteen seeds of each genotype were sown in each pot in three replications. Soils were analysed as per the method reported by Jackson (1967).

(III) Effect of temperatures (^{0}c)

Seeds of eight genotypes were put in sterilized petri dishes with single layer of ordinary filter paper. Before sowing, the seeds were thoroughly washed and soaked in distilled water for 24 hours. Further, to avoid the fungal infection the seeds were properly treated with fungicides (Thiram 75 D). The experiment was conducted for four different temperature treatments viz 5^{0}c, 15^{0}c, 25^{0}c and 35^{0}c. Twenty five seeds were put on each petriplate and each treatment was replicated thrice. The experiment was maintained in BOD incubator under controlled temperature (flexible$\pm$2^{0}c) and other factors being uniform.

(IV) Effect of different colours of light

Different colour treatment were adjusted by wrapping tube light in BOD incubator with cellophane paper of respective colours. Similar sterilization, fungicide treatment and method of sowing in petriplates was applied as done in case of temperature treatment. Other factors (temperature and moisture etc.) uniform maintained during the experiment.

Data recording

Data on seed germination was recorded on alternate days from the date of first emergence to the last emergence. At final emergence, period and a total count of germinated seeds was recorded and percentage germination was worked out for all the treatments. Finally, mean values were inversely transformed and statistical analysis was done in three factorial randomized block design.

(3) Genotypic stability

A group of eight genotypes was selected from available genetic stock of butterfly pea (*C. ternatea*). The genotypes of diverse origin were collected from different parts of Delhi, Tamil Nadu, Rajasthan and Uttar Pradesh. The group contained sufficient genetic variability for major and minor genes. A brief picture of magnitude of qualitative and quantitative traits for each entry are given in Table 3. The material was grown in randomized block design with three replications in a plot size of 3m x 4m. Row to row distance was kept to 0.5 m accommodating eight rows of 3 m long in each plot. Plant to plant distance was adjusted at seedling stage at 15-20 cm during the kharif 1990. The trial was conducted strictly under rainfed conditions and with the naturally available soil nutrients only. It was repeated for two more consecutive years.

Table 3: Source of origin, qualitative and quantitative characters of selected strains of Clitoria ternatea

Genotypes	Source	Qualitative characters				Quantitative characters			
		Seed colour	L/S ratio	Crude protein %	IVDMD %	Plant height (cm)	Branch number	Green fodder/ plant (g)	Dry fodder/ plant (g)
ILCT - 213	Delhi	Dark grey dotted	1.08	26.14	72.4	74.5	13.5	72.6	20.7
ILCT - 215	Delhi	"	1.45	25.45	72.0	66.7	15.0	55.9	16.0
ILCT - 221	Delhi	Bluish grey dotted	1.50	25.60	73.6	67.6	13.4	65.4	18.6
ILCT - 249	Delhi	"	1.31	26.04	74.2	75.6	14.4	71.3	23.1
ILCT - 261	Tamil Nadu	Brown	1.41	23.78	71.8	73.4	13.8	77.2	22.5
ILCT - 269	Rajasthan	Brown	1.54	25.67	73.5	80.4	15.2	74.1	22.2
ILCT - 272	Rajasthan	Black	1.51	21.72	72.4	72.8	17.0	72.1	18.6
ILCT - 278	Uttar - Pradesh	Black	1.55	25.78	74.0	65.0	16.7	70.0	21.0

Data recording

Observations were recorded on five randomly selected competitive plants from four central rows in each plot. The characters studied were green fodder yield/plant (g), dry matter/ plant (g), plant height (cm), branch number per plant, leaf-stem ratio. Four yield attributes viz., green fodder yield (t/h), dry fodder yield (t/ha) and seed yield (t/h) were also studied on plot basis. Observations for crude protein yield were recorded on sample basis drawn from each genotype and replication. The values were converted into t/h. Statistical analysis was carried out for randomized block design (RBD) using standard procedures (Panse & Sukhatme, 1968). Analysis for gene *X* environment interaction and stability was done as per model of Eberhart and Russell, 1966.

(4) Relative growth rate (RGR)

A set of eight genotypes of butterfly pea was sown in RBD with three replications. Sowing was done in the first week of July 1991. Each plot (3 x 2.5 m) had 3 m long five rows spaced at 0.5 m and 0.25 m between the rows and plants respectively.

Data recording and RGR

After 40, 50 and 60 days growth, five plants were randomly selected and harvested 10 cm above the ground level. These plants were selected from central row of the plot. Leaves and stem of plant were separated, oven dried and data on dry matter was recorded. RGR expresses the increase of dry weight in specific time period in relation to initial weight and RGR (g/g/day) can be calculated as; RGR = Log w2 - Log w1 divided by t2 - t1 (on dry matter basis) and was computed at two growth period 40-50 days growth and 50-60 days growth. These are said to be RGR-I and RGR-II. Correlation coefficients was worked out between the RGR of leaf, stem and leaf + stem (entire plant) for respective periods of growth. Correlation coefficient was also worked out between dry matter yield/plant (g) and their respective RGR values at different harvest times (Singh and Singh ,1988).

(5) Compatibility of *C. ternatea* with different grasses

The study on various grass-legume intercropping system was conducted at NRCAF,Jhansi during the July 1989 to December 1992. The soil of experimental site was clay loam (approximately 46.8% sand, 39.0% clay and 14.1% silt) with 7.5 pH and soil status was 0.4% organic carbon with, available nitrogen, phosphorus and Potash 161-0, 7.5 and 268 kg/ ha respectively.

The mix-cropping experiment was conducted with following species and their combination treatments.

Grass components :

(1) *Chrysopogon fulvus* (Spreng) Chiov.

C.fulvus commonly known as Dhawalu grass is a perennial grass distributed through out the hilly regions of India, Afghanistan, Pakistan and Srilanka. This grass is one of the principal constituent species of *Sehima-Dichanthium* grass cover in the Central and Southern plateau in the country (Dabadghao and Shankarnarayan, 1973). The grass can be grown even on rocky substratum under low to medium rainfall situations. Its herbage productivity under degraded rangeland situations is very low (0.7-1.2 t/h dry forage yield in 1-2 cuts). The quality of herbage is also poor.

(2) *Heteropogon contortus* (L) Beaur. ex Roem & Schultt

H.contortus, is a perennial grass and commonly known as spear or black spear grass and locally called as 'Lampa ghas'. It is also the main component of *Sehima-Dichanthium* grass cover of India (Dabadghao and Shankarnarayan, 1973). It is widely distributed throughout the grasslands of tropics and subtropics and has high adaptability to degraded poor sandy loam to clay soils with 5-7.5 pH. It is most palatable at pre-flowering stage.

(3) *Cenchrus ciliaris* Linn

C.ciliaris, commonly known as Buffel or Anjan grass constitutes an important grass component of the *Dichanthium-Cenchrus and Lasiurus* grass cover of India and grows predominantly in the arid and semi-arid areas of Gujrat, Rajasthan, Haryana, West and Central Uttar-Pradesh and northern Madhya-Pradesh. Buffel is a perennial grass, 110-145 cm erect or decumbant. It is highly adaptive to sandy and dry regions. The productivity of this grass under natural range conditions is very low (0.2 to 0.3 t/h dry matter). It resists drought condition and is considered to be the most nutritious among native grasses. It has good soil binding capacity and may check soil erosion. Grazing animals have special liking for this grass.

Tree legume

Leucaena leucocephala var. Glabiata *L. leucocephala* Lam de Wit

Subabul was introduced in domestication areas of Forest Research Institute, Dehradun as early as 1931 (Krishnaswami, 1956) and in Andmans it was grown as hedge row (Parkinson,1977). Later, Hawain strains were introduced in Bombay state in 1948 from Philippines (Qureshi and Desai, 1981). It is adopted to degraded and denuded lands of medium rainfall zones. It yields 8 - 20 t/h/yr forage and about 95-96 t/h/yr fuelwood and also enriches the soil fertility. *Leucaena leucocephala* is being intensively evaluated for its varietal improvement (Gupta, 1988) and interplanted with traditional/non-traditional fodder crops and results have been quite encouraging in favour of mix cropping with cereals and grasses (Pathak,1988; Relwani and Khandale, 1988). The green fodder and its hay can be used as a rich source of proteinous diet for animals and is recognised as 'Protein bank' (Hutton 1988).

A. Main legume species:

Clitoria ternatea	(Ct)

B. Grass species:

(i) *Chrysopogon fulvus*	(Cf)
(ii) *Heteropogon contortus*	(Hc)
(iii) *Cenchrus ciliaris*	(Cc)

C. Tree legume species

Leucaena leucocephala	(Sbl)

Treatments

T-1. Pure *C.ternatea*	(Ct)
T-2. Pure *C. fulvus*	(Cf)
T-3. Pure *H. contortus*	(Hc)
T-4. Pure *C. ciliaris*	(Cc)
T-5. *C.ternatea* + *C.fulvus*	(Ct + Cf)
T-6. *C.ternatea* + *H.contortus*	(Ct + Hc)
T-7. *C.ternatea* + *C.ciliaris*	(Ct + Cc)
T-8. *C.ternatea* + *L.leucocephala*	(Ct + Sbl)
T-9. *C.fulvus* + *L.leucocephala*	(Cf + Sbl)
T-10. *H.contortus* + *L.leucocephala*	(Hc + Sbl)
T-11. *C.ciliaris* + *L.leucocephala*	(Cc + Sbl)
T-12. *Clitoria* + *Chrysopogon* + *Leucaena*	(Ct + Cf + Sbl)
T-13. *Clitoria* + *Heteropogon* + *Leucaena*	(Ct + Hc + Sbl)
T-14. *Clitoria* + *Cenchrus* + *Leucaena*	(Ct + Cc + Sbl)

The experiment was laid out during the first week of July 1990 in randomized block design with three replications. The plot size was 8 x 5 m and 1 m distance between the plots. Transplanting and sowing were done as follows:

(I) Pure crop of grass species were planted at 50 cm distance between the rows and also the plants in each row. In case of *Clitoria* 12-15 plants were maintained per running meter.

(II) In case of grass legume mixtures alternate row of *Clitoria* and grass species were sown maintaining a distance of 50 cm between the rows of grasses and *Clitoria*.

(III) For three species intercropping experiments each plot (8 x 5 m) was divided into two equal parts of 4 x 5m. In half of the plot *L.leucocephala* (Sbl) were transplanted at 1 m distance between the inter row of grass species.

At the time of sowing/planting no organic or inorganic fertilizer was applied. Establishment of *Clitoria* and grasses were 80-100 % whereas subabul needed some gap filling (one or two plants) in a few plots.

Data recording

Data on various growth parameters, fodder yielding attributes and quality aspects were recorded in all the grasses & legumes at the time of harvesting. Two cuts were taken in all the inter-cropped species, first cut in Ist week of August and IInd cut in the last week of September. The cut in *C.ternatea* and other grass species was taken at 10 cm height from the ground while subabul plants were lopped at 1 m from the base at every cutting.

Plant height (cm)

Plant height in *C.ternatea* was recorded on three randomly selected plants from each plot and height was measured from the ground level of the plant to the apex of main shoot. In grass species largest tiller was measured from three randomly selected tussucks.

Branch number

Number of branches emerging on the main shoot (right from base to apex) were counted on three randomnly selected plants in each plot in *C.ternatea* whereas in grasses number of tillers (sprouts arising from the base of the grass plant *i.e.* tussucks) were counted from selected tussucks from all the plots and replications.

Green fodder yield (t/h)

After recording the data on various growth parameters on three randomly selected

plants, green fodder (stem+leaves) of some plants were recorded (g) and sampled. Green fodder was recorded after complete harvest of plot. After averaging the yield was computed and converted into t/h.

Dry matter yield (t/h)

500 g sample from each plot and plant basis samples were oven dried at 60-70°C for more than 48 hr. and both the samples were weighed and dry matter per plant (g) and dry matter yield (t/h) was worked out.

Crude protein yield (t/h)

Methods of estimation of crude protein content were followed as mentioned earlier (A.O.A.C.,1999). After conversion and multiplying with factor the CP yield was worked out in t/h. In the text C-1 and C-2 denotes first and second cutting, respectively. Similarly the treatments are denoted as T-1 to T-14 while Y-1, Y-2 and Y-3 shows the first, second and third year, respectively.

Meteorological observations

Meteorological data on rainfall (mm), temperature (° C), humidity (%) and evaporation (mm/day) for the period of June 1989 to December 1992 is given in Figure 2-4. During the experimentation period minimum precipitation 668.8 mm was received during the establishment year 1989 while maximum rainfall 1161.2 mm was recorded in 1990 followed by 1991 and 1992. Highest number of rainy days were recorded in second year i.e. 1990 which is given below;

Year	Rainfall mm	Number of rainy days
1989*	668.8*	27
1990	1161.2	46
1991	957.7	35
1992	786.4	44

* Rainfall received from June - December, 1989.

The onset of monsoon was well in time in 1989. Early rains were recorded in June and July ,while most of the precipitation (more than 80% of the total rainfall) was received during

Rainfall (mm) and relative humidity (%) pattern during study period

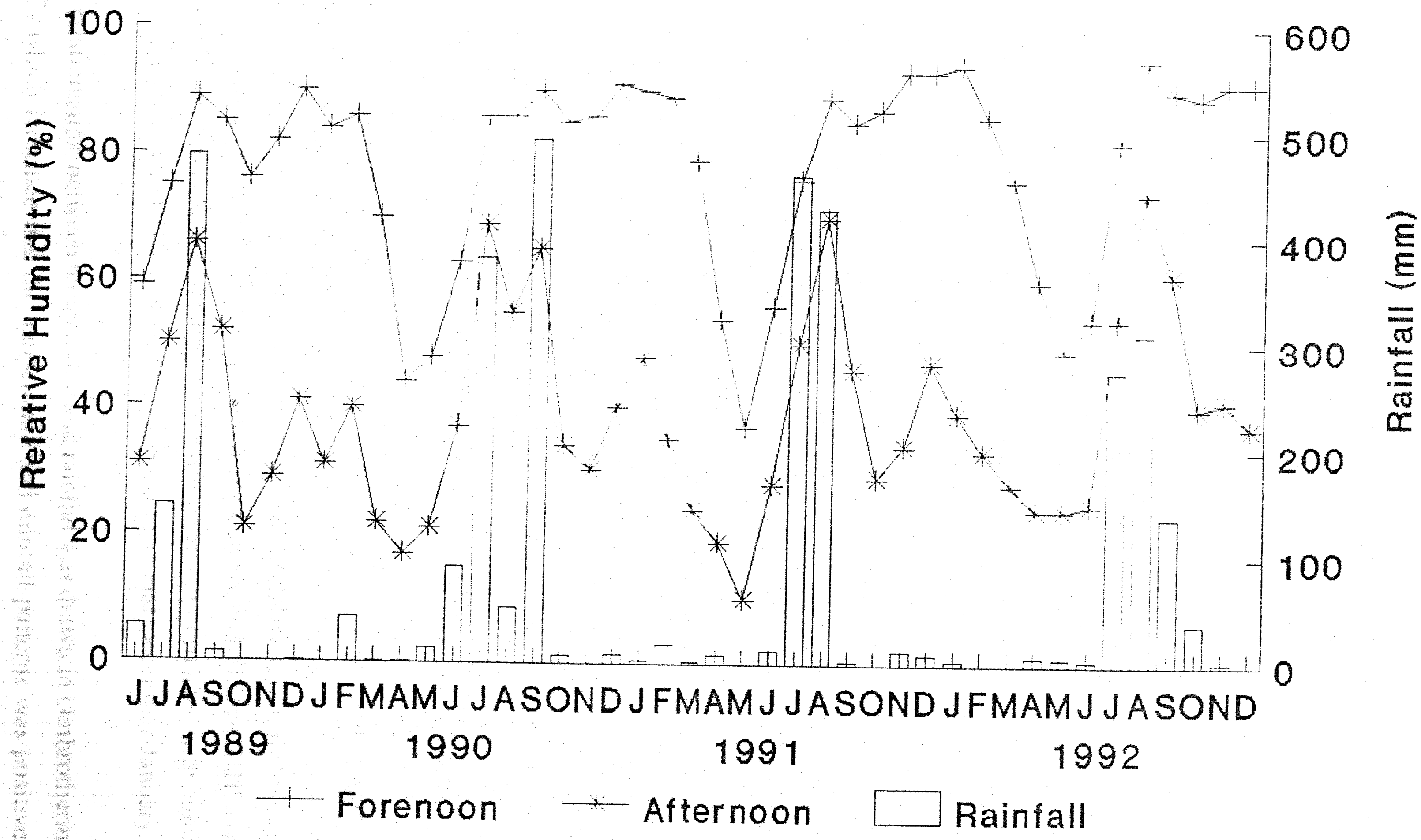


Figure-2

the month of August. From September onward upto end of the year, a continuous dry spell was experienced.

The year 1990 experienced normal onset of monsoon during third week of June (25th standard week) and was well distributed in 40 rainy days throughout the monsoon season. The monsoon remained active upto 38th standard week and during last spell more than 340 mm rainfall was recorded within 5 rainy days (15th to 19th September). A good amount of precipitation (39.5 mm) was also recorded in second week of February. Maximum temperature (44.8°C) was recorded during the last week of May (29th May) while minimum (6.1°C) was observed in first week of January. Highest rate of evaporation (19.8 mm/day) was recorded during the last week ending on 29th May (Fig. 2,3 & 4).

During 1991, monsoon rains were received quite late in 29th standard week (third week of July) and maximum precipitation (415 mm) was recorded in July followed by September. The monsoon was most effective during 7 weeks and over all normal rains (878.2 mm) were received in 24 rainy days but for crop growth the distribution was not favorable. A good amount of raifall (22.2 mm) was also received during rabi season. High value with respect to temperature (45°C) and evaporation (21.0 mm/day) was recorded during the last week of May and first week of June 1991 respectively.

Again during the year 1992, a late onset of monsoon was experienced in second week of July (28th standard week) thereafter, the monsoon was effective for next 10 weeks. During this period a total rainfall (723 mm) was well distributed in 36 rainy days. In second week of October about 38 mm rainfall was observed in three rainy days. Maximum and minimum temperature were recorded on 8th June (46.0°C) and December 29th (6.2°C), respectively. Highest rate of evaporation (18-0 mm/day) was recorded on June 8th (Fig.4).

During the course of experimentation, on an average, precipitation was mainly received during the period of June to September every year. The late onset of monsoon and decreasing trend for mean total rainfall was observed from 1989 to 1992. Relative humidity (%) and rainfall (mm) trend is being presented in Fig.2. An increasing trend in both sides of RH% was observed from establishment year to terminating year and was positively correlated with rainfall pattern. Generally, the maximum RH% was recorded in September and December-January.

An inter relationships between temperature and rainfall was drawn in Ombrothermic diagram (Fig. 3) which indicated that the temperature and rainfall patterns was positively correlated. An increasing trend in temperatures and decreasing trend in precipitation (with scanty or without rains) was experienced during the Kharif season in respect of September, 1989, 91 and August 90 while during 1992 a normal trend in both the parameters was recorded.

Ombrothermic diagram obtained during study period

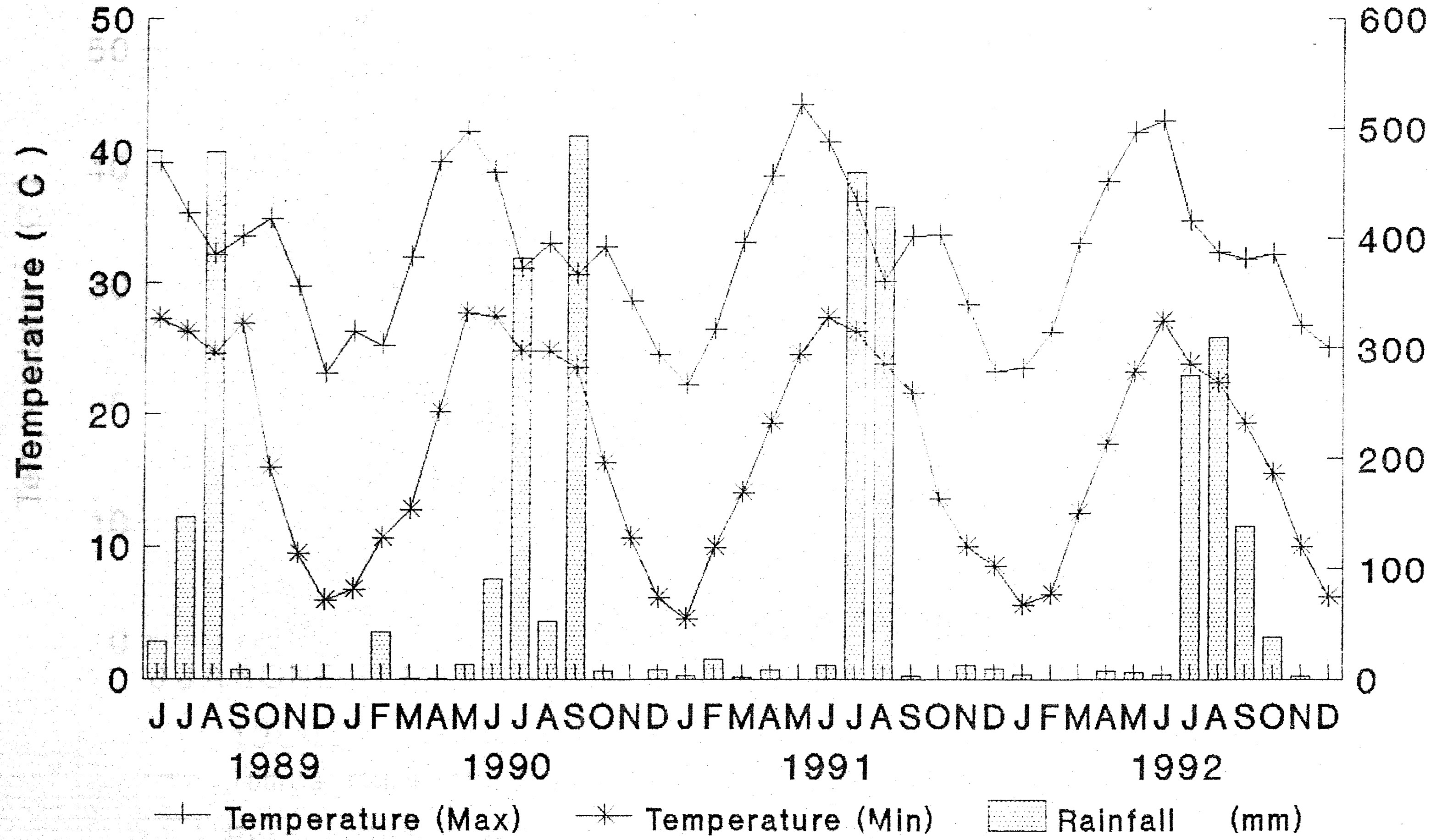


Figure-3

Temperature(°C) and evaporation (mm/day) pattern during study period

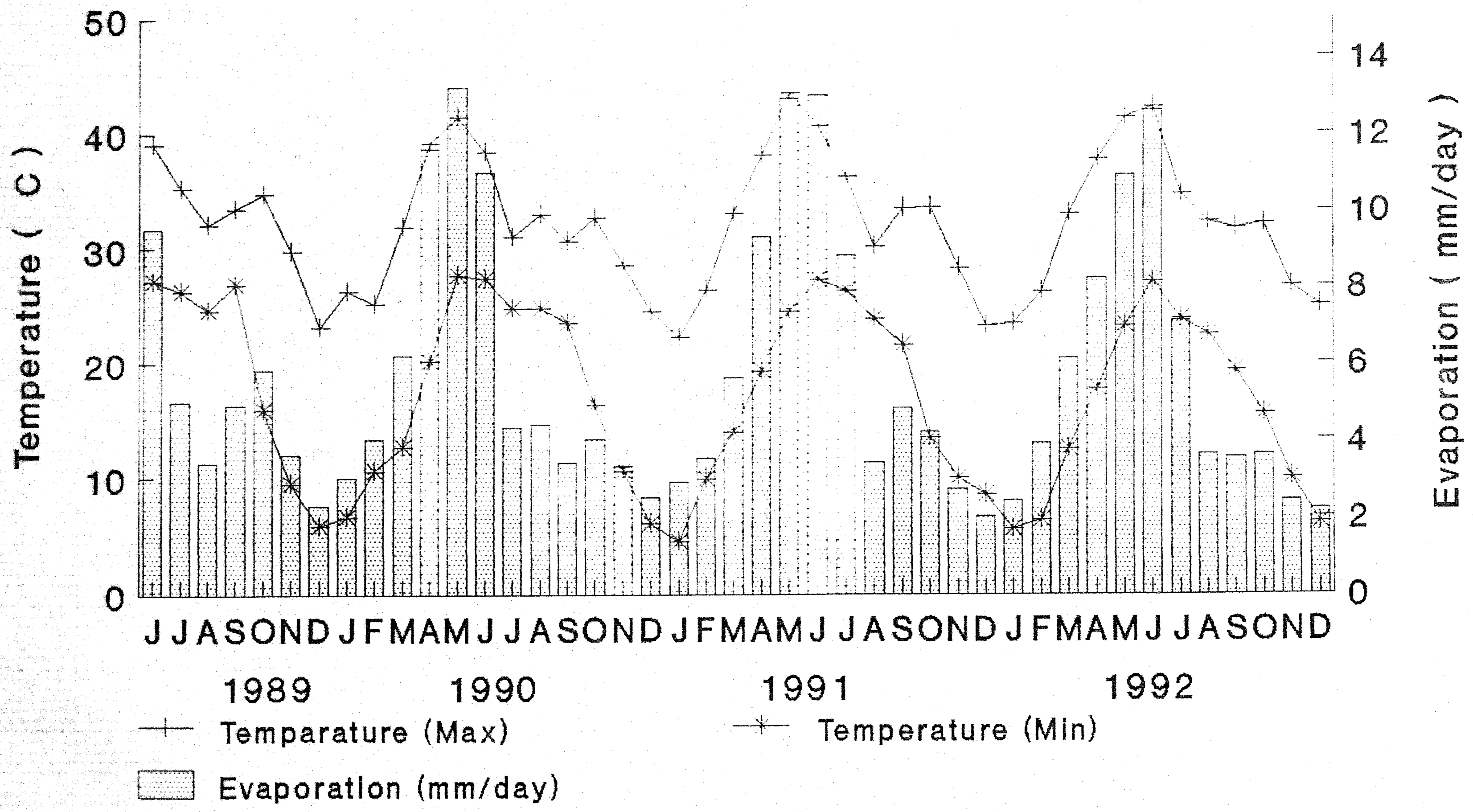


Figure-4

4

RESULTS

Genetic diversity in 92 diverse germplasm lines of *Clitoria ternatea* collected from several geographical regions of India was studied. A majority of the genotypes were collected from arid and semi-arid regions of Rajasthan, Gujrat, Delhi, Uttar Pradesh, Madhya Pradesh and Maharashtra. A few materials were also collected from southern coastal tracts of Tamil Nadu and warm humid situations of Bihar and West Bengal. Details of the materials collected from the different regions are presented in Table 4 and Figure 1.

Variations in seed coat colour

Striking variation were observed in seed coat pigmentation of Clitoria materials collected from the different regions. The entire gene pool may be classified into four distinct groups:

Dark black seeds

The seed coat of this group possess dark and shining black colour. Sixteen accessions fall in this group.

Grey speckled seeds

Dark grey or light blackish angular specklings were present against the greyish background of the seed coat of this group. This group has the largest number of fifty three accessions.

Brown dotted seeds

A fine sprinkling of grey or dark dottings present all over against the buff background of seed coat. This group is represented by nine genotypes.

Dark brown seeds

A fine sprinkling of grey or dark dottings present all over against the greyish background of seed coat. This group is represented by fourteen genotypes (Plate-2).

1

Butterfly Pea (*Clitoria ternatea*)
at a glance

Table 4: Genetic resources and their source of origin in *Clitoria ternatea*

Source	Number of accessions	Name of accessions
Rajasthan	30	ILCT- 225, 226, 227, 228, 229, 230, 246, 247, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276 and 298.
Uttar-Pradesh	21	ILCT- 223, 224, 239, 240, 241, 243, 244, 245, 262, 263, 264, 265, 266, 277, 278, 279, 280, 281, 288, 289, and 290.
Delhi	15	ILCT- 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 248 and 249.
Madhya-Pradesh	09	ILCT- 231, 232, 233, 282, 283, 284, 285, 286 and 287.
Gujrat	07	ILCT- 235, 236, 237, 238, 291, 292 and 293.
Maharashtra	04	ILCT- 294, 295, 296 and 297.
Tamil Nadu	02	ILCT- 261 and 299.
Bihar	02	ILCT- 222 and 300.
West Bengal	02	ILCT- 234 and 242.

Genepool of *Clitoria ternatea* and its source of origin

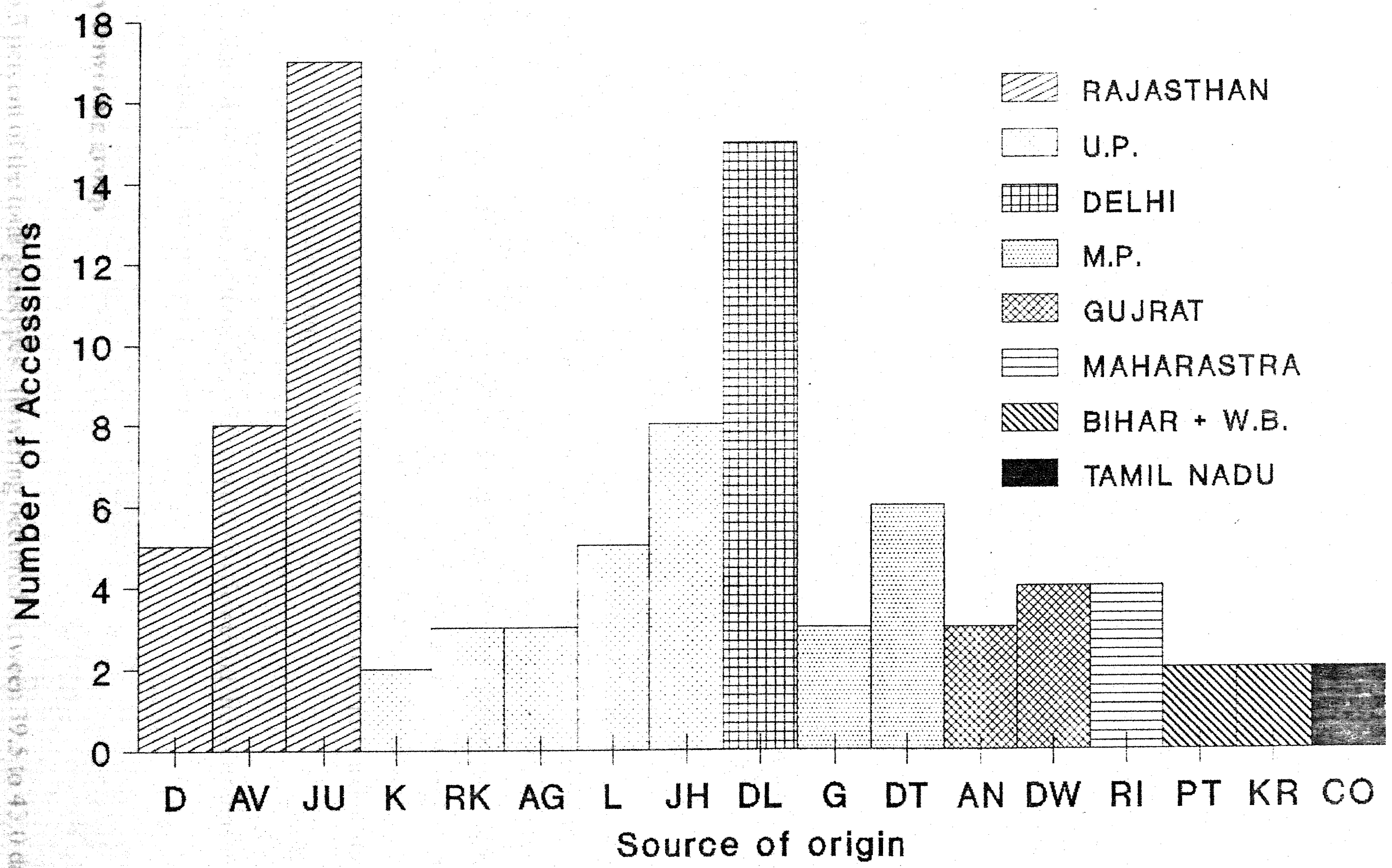


Figure-1

Germplasm evaluation

92 germplasm lines of butterfly pea were evaluated for various fodder yielding attributes and other related parameters such as days to flowering, plant height (cm), branch number, secondary branch number, branch length (cm), number of leaves/plant, green fodder/plant (g), dry fodder/ plant (g), leaf-stem ratio and crude protein contents (%) etc. The genetic evaluation of the materials was based on the study conducted over three crop growth seasons *i.e.* July 1989 to December 1992 under rainfed situation. The range mean and coefficient of variation of ten plant characters is presented in Table 5. A wide range of variation in the means of different characters for the different genotypes was observed . Amongst all the characters studied maximum variation (CV 35%) was observed in the green fodder yield /plant followed by number of leaves / plant (CV 31%), leaf / stem ratio (CV 27%) and minimum in branch number /plant (CV 14%) and days to flower (CV 15%). For better apprehension of the variability the means of three year data of each plant character was further classified into low, medium and high groups (Table 6).

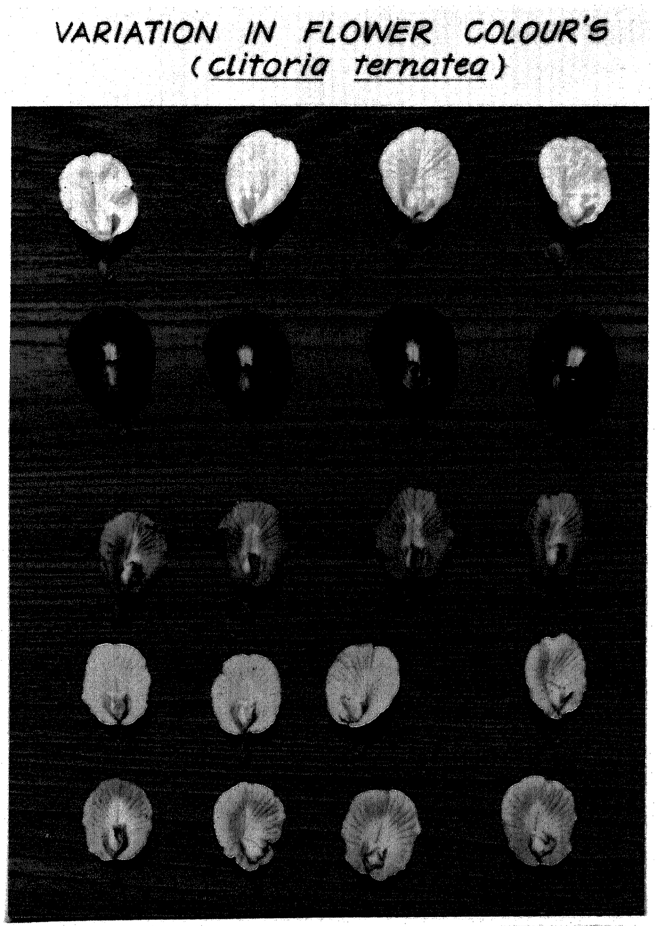
Days to flowering

Flowering in *Clitoria ternatea* takes place during the month of August and early September. Significant variations were observed for days to flower in the different materials. These differences in flowering were, however, more clearly marked in the first two seasons of crop growth viz. 1989 and 1990 than during the third year of growth *i.e.* 1991 (Table 7). The flowering period reduced progressively from 22 days in the first year to 13 days in second year and only 9 days in the third year. Flowering in *Clitoria* was preceded by 37 to 41 days of vegetative growth and continued upto 60 days of growth in the first year and 54 days in the second year, but in the third year the flowering terminated after 46 days of growth. Pooled data over three years revealed wide genetic diversity (CV 15%) for days to flowering in *Clitoria* (Table 5). However in any single year of growth value of coefficient of variation did not exceed more than 4% (Table 7) indicating thereby a differential environmental influence in different genotypes for days to flowering.

On the basis of mean values of three year data on days to flowering the germplasm has been classified into the following groups(Table 6);

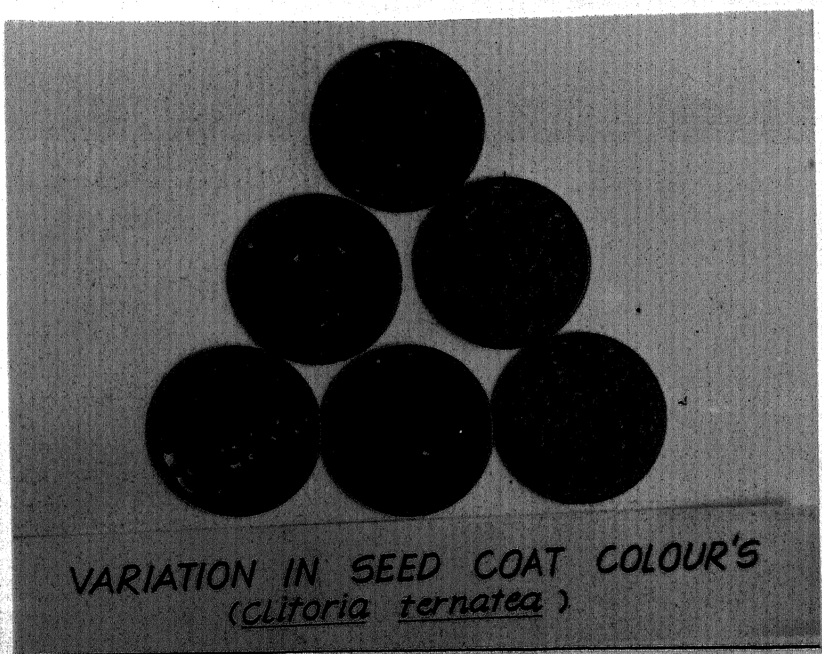
Early flowering group

In 16.3 percent of the total genotypes flowering occurred between 39.5 to 43.0 days.



Variation in flower colour in *Clitoria ternatea*

2



Variation in seed coat colour in *Clitoria ternatea*

3

Table 5: Mean, range and coefficient of variation for different morphological and fodder yielding attributes in 92 genotypes of *C. ternatea*.

Characters	Range	Mean	CV(%)
Days to flower	39.5-49.6	44.55 ± 1.18	15.05
Plant height (cm)	53.2-94.9	73.88 ± 3.15	20.72
Branch numbers	8.0-17.9	12.86 ± 0.93	14.00
Number of secondary branches	10.0-24.8	17.40 ± 1.30	18.00
Branch length (cm)	54.1-95.1	73.68 ± 3.45	20.86
Leaf numbers	90.4-183.5	136.80 ± 5.36	31.00
Green fodder yield (g)	39.3-97.7	68.00 ± 2.16	35.00
Dry matter yield (g)	11.01-26.66	17.96 ± 1.35	24.06
Leaf-stem ratio (dry matter basis)	0.64-1.24	0.93 ± 0.09	27.04
Crude protein content (%)	20.13-26.99	23.56 ± 0.56	17.54

Medium flowering group

A majority of the accession (64.1%) flowered between 43.0 - 46.3 days.

Late flowering group

In 19.6 percent genotypes the flowering occurred between 46.3-49.6 days (Table 6).

Plant height (cm)

On the basis of mean values of data over three years the plant height of the different genotypes at 55 days of growth ranged between 53 to 95 cm and showed wide genetic diversity (CV 20.7%). The germplasm line ILCT-222 from Bihar attained a maximum plant height of 94.9 cm while the accession ILCT-297 from Maharashtra was 53 cm tall (Table 5). Maximum number of genotypes (48.9%) had a moderate plant height (67.1-81.0 cm), 32.6% were short statured (53.2-67.0 cm) and 18.5% germplasm lines had tall plants ranging from 81-95 cm (Table 6). The genotypic differences for plant height were significant in all the years (Table 7). In some of the genotypes there was a progressive increase in the maximum plant height from 90 to 123 cm from first to third year of plant growth.

Branch number per plant

Wide range of diversity in branch number/plant was observed in butterfly pea in all the three years (Table 7).The genotypic differences for branch number were highly significant in the second year of growth and moderate in others. The branch number ranged between 8.0-17.9 branches/plant with 14.0% CV over the years (Table 5). Maximum number of branches were observed in ILCT-272 (17.9) from Rajasthan and minimum in ILCT-233 (8 branches/plant) from Madhya Pradesh. Majority of cultivars (51.1%) showed medium number of branches (11.4-14.6), 34.8% genotypes were with low number of branches (8.0-11.3 branches/plant) and 14.1% genotypes were highly branched type (14.7-17.9 branches/plant). Number of branches were maximum in second year (14.87) in comparison to first (12.1) and third year 9.8 branches (Table 7).

Number of secondary branches

Wide range of genetic diversity for the number of secondary branches/plant were observed in butterfly pea in the different years. The genotypic differences were highly significant

Table 6: Range and percentage distribution of 92 genotypes of *C. ternatea* in different groups.

Character and groups		Range	Percent cultivars
1. Days to flowering			
Group -I	Early flowering	39.5-42.9	16.3
Group -II	Medium flowering	43.0-46.3	64.1
Group -III	Late flowering	46.4-49.6	19.6
2. Plant height (cm)			
Group -I	Dwarf plants	53.2-67.0	32.6
Group -II	Medium plants	67.1-81.0	48.9
Group -III	Tall plants	81.1-94.9	18.5
3. Branch number			
Group -I	Low branches	8.0-11.3	34.8
Group -II	Medium branches	11.4-14.6	51.1
Group -III	Highly branched	14.7-17.9	14.1
4. Secondary branch number			
Group -I	Low numbers	10.0-14.9	38.0
Group -II	Medium numbers	15.0-19.8	55.4
Group -III	High numbers	19.9-24.8	6.6
5. Branch length (cm)			
Group -I	Smaller branches	54.1-67.7	41.3
Group -II	Medium branches	67.8-81.0	45.7
Group -III	Larger branches	81.1-95.1	13.0

(Contd..6)

(Contd..6)

Character and groups		Range	Percent cultivars
6. Number of leaves			
Group -I	Low leaf number	90.4-121.4	47.8
Group -II	Medium leaf number	121.5-152.4	31.5
Group -III	High leaf number	152.5-183.6	20.7
7. Green fodder yield/plant (g)			
Group -I	Low yield	39.3-58.8	54.3
Group -II	Medium yield	58.9-78.2	35.9
Group -III	High yield	78.3-97.7	9.8
8. Dry matter yield/plant (g)			
Group -I	Low yield	11.01-16.20	42.4
Group -II	Medium yield	16.21-21.40	39.1
Group -III	High yield	21.41-26.99	18.5
9. Leaf-stem ratio			
Group -I	Low leafiness	0.64-0.83	23.9
Group -II	Medium leafiness	0.84-1.04	53.3
Group -III	High leafiness	1.05-1.24	22.8
10. Crude protein content %			
Group -I	Low	20.13-22.43	21.7
Group -II	Medium	22.44-24.73	46.7
Group -III	High	24.74-26.99	31.6

for all the three years (Table 7). The number of secondary branches/plant over the years (Table 5) ranged between 10.0-24.8 (with 18% CV). Based on the mean values of three years (Table 6) a majority of the genotypes (55.4%) had medium number of secondary branches (15.0-19.8 /plant), 38.0% had low number (10-15 per plant) and 6.6% cultivars had the highest number (20-24.8 /plant). Lowest number of secondary branches were observed in the establishment year (12.4 /plant) which significantly increased during second year (19.3) but slightly decreased (16.7) in third year (Table 7).

Branch length (cm)

Considerable variations were observed in branch length among genotypes (Table 5) which ranged between 54.1-95.1 cm (CV 20.86%). The majority of genotypes (45.7%) had medium branch length followed by 41.3% small length and 13.0% with large branches (Table 6). The branch length showed significant genotypic differences in the different years. But the average branchlength reduced progressively from 77cm to 67cm over the years (Table 7).

Number of leaves/plant

Significant genotypic differences were observed for number of leaves per plant and their mean values over the years varied from 90.4-183.5. Very high values of CV (31.0 %) indicated wide genetic diversity for this character (Table 5 and 7). Majority of the genotypes (47.8%) had low number of leaves, 31.5 % with moderate and 20.7 % with high number of leaves per plant (Table 6).

Significantly higher number of leaves (171 per plant) were observed in second year of growth while in first and third year the leaf number was similar (Table 7). The lowest number of leaves were recorded in genotype ILCT-287 from Madhya Pradesh while ILCT-213 from Delhi was the most leafy type.

Green fodder yield/plant (g)

Based on an average of three years data, the green fodder yield/plant (g) of genotypes ranged between 39.3 - 97.7 (g). High values of CV (35%) indicated wide genetic diversity for the character (Table 5). Amongst the genotypes the maximum number of cultivars (54.3%) were low yielding, followed by 35.9% moderate and 9.8% high yielding types (Table 6). Second year of growth was most productive for green fodder yield/plant (72.6 g/plant) followed by third (59.3 g/plant) and first year (50.1 g/plant). Genotype ILCT-253 from Rajasthan was the lowest yielder while Maharashtra material ILCT-295 was the highest yielding type.

Dry matter yield /plant (g)

Significant genotypic differences were observed for dry matter/plant in the different years. The mean dry matter yield/plant ranged between 11.01-26.66 g over the years. A wide genetic diversity was evident from high values of CV (24.06%). Amongst the genotypes a majority of genotypes (42.4%) were low yielder, followed by (39.1%) moderate types and 18.5% high yielding types (Table 6). The trend of green fodder and dry matter yield / plant was almost similar in all the three years (Table 7). The lowest dry matter yielding type was ILCT-263 (11.1 g) from Uttar-Pradesh and the highest yielding type was ILCT-295 (26.66 g/plant) from Maharashtra state.

Leaf-stem ratio

The leaf-stem ratio of genotypes showed significant differences in the different years. Based on an average of three years the leaf/stem ratio of genotypes ranged between 0.64 - 1.24 and a wide range of genetic diversity in the material was evident (CV 27.0 %). Amongst the genotypes highest number of cultivars (53.3%) had moderate L/S ratio while 22.8% of total genotypes were relatively more leafy types. The leafiness was comparatively higher in the establishment year (L/S 1.12) followed by third and second year with leaf/stem ratio 0.89 and 0.82, respectively, (Table 7). The minimum (L/S 0.64) and maximum (L/S 1.24) leaf-stem ratio was observed in Rajasthan genotypes ILCT-274 and ILCT-251, respectively.

Crude protein content (%)

Wide genetic diversity (CV 17.54%) and significant genotypic differences were observed for crude protein percentage which ranged between 20.13 - 26.99% on dry matter basis (Table 5). Amongst all the genotypes a maximum number 46.7 % of genotypes had moderate (22.4 to 24.7%) crude protein content, 31.6% high crude protein (24.74 to 26.99%) and 21.7% poor protein content (20.13 to 22.43 %) as presented in Table 6.

Crop growth conditions in the different years significantly influenced crude protein content (CP) in the forage. There was an increasing trend in the crude protein content of the forage from 21.27 to 25.85% from first to third year of growth (Table 7). Highest and lowest values for CP content were observed in Rajasthan materials ILCT-267 (26.99%) and ILCT-275 (20.1%).

Table 7: Range, mean and coefficient of variation in phenotypic characters, yield and quality parameters of C. ternatea genepool.

Character	Range	Mean	CV(%)	'F' Value
1. Days to flowering				
I Year 1989-90	38.00-60.33	46.33 ± 1.16	3.07	27.07
II Year 1990-91	41.00-54.00	46.29 ± 0.64	1.70	45.96
III Year 1991-92	37.00-46.00	41.40 ± 1.42	4.22	4.82
2. Plant height(cm)				
I Year 1989-90	52.00-89.43	72.30 ± 6.11	10.36	3.83
II Year 1990-91	51.33-108.53	77.85 ± 9.94	15.64	4.15
III Year 1991-92	40.00-123.66	64.84 ± 8.77	16.57	3.76
3. Primary branch numbers				
I Year 1989-90	8.20-16.20	12.15 ± 1.85	18.71	1.88
II Year 1990-91	8.06-26.87	14.87 ± 1.81	14.96	11.85
III Year 1991-92	6.20-14.63	9.87 ± 1.76	21.87	3.68
4. Secondary branch numbers				
I Year 1989-90	4.66-30.33	12.42 ± 2.36	23.25	6.86
II Year 1990-91	10.16-29.00	19.36 ± 2.83	17.89	4.42
III Year 1991-92	8.16-25.66	16.69 ± 2.41	17.70	3.63
5. Branch length (cm)				
I Year 1989-90	52.66-109.0	76.80 ± 9.40	15.00	2.16
II Year 1990-91	84.33- 93.0	169.33 ± 9.08	16.04	5.30
III Year 1991-92	71.66-155.33	117.30 ± 7.79	14.18	6.79

(Contd...7)

Character			Range	Mean	CV(%)	'F' Value
6. Leaf number/plant						
I	Year	1989-90	70.66-198.66	111.04 ± 20.32	22.42	3.14
II	Year	1990-91	84.33-293.00	171.00 ± 23.88	17.11	7.64
III	Year	1991-92	71.66-155.33	104.44 ± 14.33	16.03	4.52
7. Green fodder/plant (g)						
I	Year	1989-90	30.86-108.30	50.16 ± 8.37	22.44	4.77
II	Year	1990-91	33.63-132.33	72.61 ± 9.71	16.37	9.82
III	Year	1991-92	33.00-105.00	59.31 ± 5.85	12.07	14.72
8. Dry fodder/plant (g)						
I	Year	1989-90	8.13-23.80	14.56 ± 2.42	20.40	5.46
II	Year	1990-91	9.93-33.40	20.18 ± 2.96	17.97	7.00
III	Year	1991-92	8.20-29.86	17.28 ± 1.99	14.12	13.09
9. Leaf-stem ratio						
I	Year	1989-90	0.70-1.60	1.12 ± 0.18	19.45	2.34
II	Year	1990-91	0.56-1.55	0.82 ± 0.10	15.73	3.74
III	Year	1991-92	0.55-1.35	0.89 ± 0.10	14.15	6.49
10. Crude protein content (%)						
I	Year	1989-90	20.13-22.42	21.27 ± 0.83	17.45	6.24
II	Year	1990-91	22.43-24.70	23.56 ± 1.12	9.73	4.46
III	Year	1991-92	24.71-27.10	25.85 ± 0.72	10.42	3.62

Classification of genepool

The genetic diversity is the basic input required for any crop improvement programme. It offers scope for direct selection of elite materials as a new cultivar or helps in identifying specific traits for use in the breeding programme. In the present study, the Index Score method (Anderson, 1957) was used for identifying divergent growth forms in 92 genotypes of *Clitoriaternatea*, collected from different regions of the country.

On the basis of index score method the entire genepool was classified into 15 groups. The values of the total index score in the different groups ranged between 01-15. The materials from the different regions were distributed in the different groups with specific index score values (Tables 8 and 9). The values of the total index score of the respective groups were further classified into four major groups and their index score values are; group I: 0-4, group II: 5-8, group III : 9-12 and group IV: 13-15 (Table 10, Fig. 5). Depending upon the magnitude of the expression of all the plant traits the respective group numbers indicate; (I) low vigour expression, (II) medium vigour expression, (III) medium high vigour expression and (IV) very high vigour expression (Table 10).

Low vigour expression group

The cultivars in this group were characterised by very low expression of all or most of the characters as total index values range between 01-04 (Table 10). Out of ten accessions in this group ILCT-281 from Uttar Pradesh and ILCT-276 from Rajasthan had the lowest index values amongst all the accessions (Table 12).

Medium vigour expression group

This group constituting largest number of accessions (45) are characterised by low or medium expression of the characters in the different lines as their total index values range between 05-08 (Table 10). In this group a few genotypes also showed high expression for certain characters.

Medium high vigour expression group

This group comprising 22 genotypes was characterised by medium expression of the most and high expression of some of the characters. The total index value of the cultivars in this group range between 09-12 (Table 10).

Table 8 : Grouping of *C. ternatea* genepool in respect of their total index value(TIV), source and number of accessions.

Groups	TIV	Number of accessions	Source and number of accessions
I	1	1	UP (1)*
II	2	1	Raj (1)
III	3	3	UP (1), Raj (1) and Dlh (1)
IV	4	5	UP (2), Raj (2) and Guj (1)
V	5	7	UP (1), Raj (3), MST (1), MP (1) and Guj (1)
VI	6	10	Raj (3), MP (4), Dlh (1), Guj (1) and WB (1)
VII	7	14	Raj (6), MP (3), Dlh (3), Guj (1) and WB (1)
VIII	8	14	UP (5), Raj (5), MP (1), MS (2) and Bhr (1)
IX	9	6	UP (3), Dlh (1) and Guj (2)
X	10	7	UP (2), Raj (4) and Guj (1)
XI	11	6	UP (3), Dlh (2) and TN (1)
XII	12	3	UP (1) and Dlh (2)
XIII	13	9	UP (2), Raj (3), Dlh (2), MS (1) and Bhr (1)
XIV	14	3	Raj (2) and Dlh (1)
XV	15	3	Dlh (2) and TN (1)

* Number of accession given in parenthesis

UP: Uttar-Pradesh; Raj:Rajasthan; Dlh : Delhi; MP: Madhya-Pradesh; MS: Maharastra; Guj:Gujrat; WB: West Bengal; TN: Tamil Nadu; Bhr: Biha

Table 9: Grouping of *C. ternatea* genepool in respect of their total index value (TIV) and name of accessions.

Groups	Total index value (TIV)	Name of accessions
I	01	ILCT- 281
II	02	ILCT- 276
III	03	ILCT- 218, 259, 266
IV	04	ILCT- 256, 263, 274, 280, 291
V	05	ILCT- 230, 240, 267, 275, 287, 293 294
VI	06	ILCT- 210, 226, 233, 237, 242, 253, 255, 282, 284, 285
VII	07	ILCT- 209, 211, 217, 225, 229, 231, 232, 234, 238, 250, 252, 257, 268, 286
VIII	08	ILCT- 223, 245, 251, 258, 260, 264, 270, 273, 279, 283, 288, 296, 297, 300
IX	09	ILCT- 220, 235, 236, 265, 277, 290
X	10	ILCT- 227, 241, 246, 254, 262, 271, 292
XI	11	ILCT- 214, 216, 224, 239, 244, 299
XII	12	ILCT- 212, 219, 243
XIII	13	ILCT- 215, 222, 228, 247, 248, 278, 289, 295, 298
XIV	14	ILCT- 249, 269, 272
XV	15	ILCT- 213, 221, 261

Table 10: Percentage distribution of genotypes of *C. ternatea* in different groups, TIV, number of accession and source of origin.

	Major Groups	Range of TIV	Percentage accessions	Source and number accessions
I.	Low vigour group	01-04	11	UP (4)*, Raj (4), Dlh (2) and Guj (1).
II.	Medium vigour group	05-08	49	UP (6), Raj (17), MP (9), Dlh (4), Guj (3), MS (3), WB (2) and Bihar (1).
III.	Medium high vigour group	09-12	24	UP (9), Raj (4) Dlh (5), Guj (3) and TN (1).
IV.	Very high vigour group	13-15	16	UP (2), Raj (5), Dlh (5), MS (1), TN (I) and Bhr (1)

WB : West Bengal, UP : Uttar Pradesh, TN : Tamil Nadu

MS : Maharastra, MP : Madhya Pradesh, Guj : Gujrat

Dlh : Delhi and Bhr : Bihar

* Number of accessions are given in parenthesis

Grouping of *C. ternatea* genepool in different vigour groups

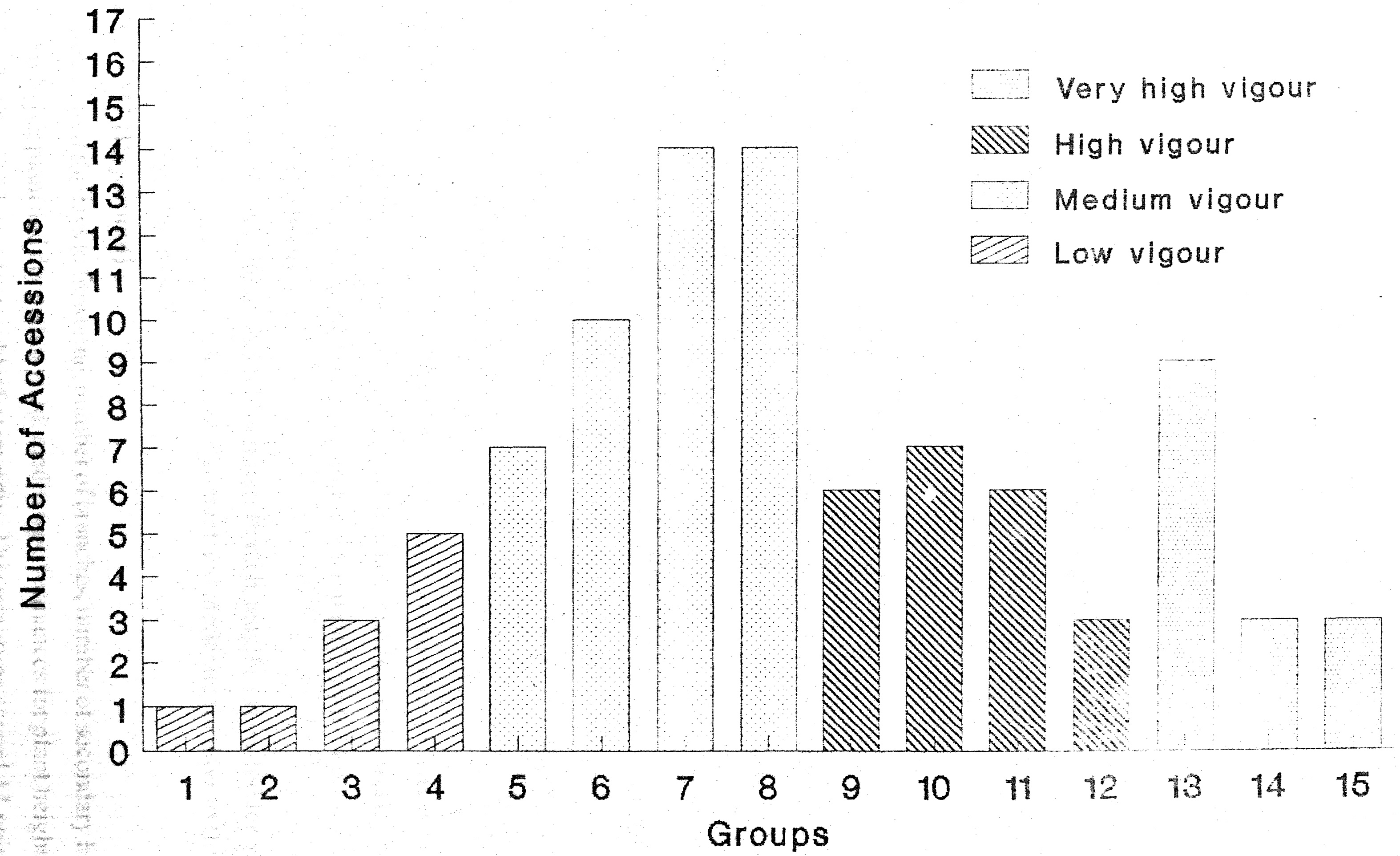


Figure-5

Very high vigour expression group

The accessions of this group were most productive forage yielders as most of the characters show maximum expression. The total index values showed a range of 13-15 (Table 10 & Fig.5) Out of 15 genotypes in this group the accessions ILCT 213 and 221 (Delhi), and ILCT 261 (Tamil Nadu) were the most aggressive plant growth types (Table 11).

Followings are,some of the superior lines showing high and very high total index values (TIV):

ILCT- 213 (Delhi)

Highly scored for plant height, branch length, number of leaves, green fodder per plant, dry matter per plant and crude protein content; while moderate values recorded for days to flower, branch number, number of secondary branches and leaf-stem ratio and scored 15 points.

ILCT- 221 (Delhi)

Highly scored for days to flower, plant height, branch length, number of leaves per plant and crude protein content; while moderate for branch number, secondary branch number, green fodder per plant, leaf-stem ratio and scored 15 points.

ILCT-261 (Tamil Nadu)

Highly scored for plant height, number of secondary branches, branch length, number of leaves and dry matter yield/plant; while moderate for days to flower, number of branches, green fodder yield per plant, leaf- stem ratio and crude protein content. This genotypes secured 15 points.

ILCT-249 (Delhi)

Highly scored for days to flower, number of branches, number of leaves and crude protein content; moderate for plant height, number of branches, number of secondary branches, green fodder yield per plant, dry matter per plant and leaf-stem ratio with 14 points.

ILCT- 269 (Rajasthan)

Highly scored for secondary branch number, branch length, green fodder yield per plant, dry matter yield per plant and crude protein content and moderate for days to flower and plant height and scoring 14 points.

ILCT-272 (Rajasthan)

Highly scored for days to flowering, number of branches, number of secondary branches, number of leaves per plant and dry matter yield; medium performances for plant height, branch length, green fodder yield per plant and leaf-stem ratio. This genotype scored 14 points.

Table 11: High, medium and low expression of characters and total index value (TIV) for 15 selected genotypes of C. ternatea and their source of origin.

Name of accession	Code	Code value	Character 1	2	3	4	5	6	7	TIV	Source of origin
	H	2	Ph	Brl	Lno	GM	DM	CP			
ILCT -213	M	1	Df	Br	Sbr					15	Dlh
	L	0	L/S								
	H	2	Ph	Br	Lno	DM					
ILCT -215	M	1	Df	Sbr	GM	L/S	CP			13	Dlh
	L	0	Br!								
	H	2	Df	Ph	Brl	Lno	CP				
ILCT -221	M	1	Br	Sbr	GM	DM	L/S			15	Dlh
	L	0									
	H	2	Df	Ph	Brl	DM					
ILCT -222	M	1	Br	Sbr	GM	L/S	CP			13	Bhr
	L	0	Lno								
	H	2	Ph	GM	DM	CP					
ILCT -228	M	1	Df	Br	Sbr	Brl	L/S			13	Raj
	L	0	Lno								
	H	2	Df	Brl	Lno	L/S	CP				
ILCT-247	M	1	Ph	Sbr	DM					13	Raj
	L	0	Df	GM							
	H	2	Df	Br	Lno	DM	L/S				
ILCT -248	M	1	Ph	Sbr	GM					13	Dlh
	L	0	Brl	CP							
	H	2	Df	Br	Lno	CP					
ILCT -249	M	1	Ph	Br	Sbr	GM	DM	L/S		14	Dlh
	L	0									

(Contd..11)

(Contd..11)

1	2	3	4	5	6
ILCT -261	H	2	Ph Sbr Brl Lno DM		
	M	1	Df Br GM L/S CP	15	TN
	L	0			
ILCT -269	H	2	Sbr Brl Lno GM DM CP		
	M	1	Df Ph	14	Raj
	L	0	Br L/S		
ILCT -272	H	2	Df Br Sbr Lno DM		
	M	1	Ph Brl GM L/S	14	Raj
	L	0	CP		
ILCT -278	H	2	Df Br GM DM CP		
	M	1	Sbr Brl Lno	13	UP
	L	0	Ph L/S		
ILCT -289	H	2	Br GM DM		
	M	1	Df Ph Br Sbr Lno L/S CP	13	UP
	L	0			
ILCT -295	H	2	Lno GM DM		
	M	1	Df Ph Bl Sbr Brl L/S CP	13	MS
	L	0			
ILCT -298	H	2	Sbr Lno GM DM		
	M	1	Df Ph Br L/S CP	13	Raj
	L	0	Brl		

H: High; M: Medium; L: Low

Df: Days to flowering; Ph: Plant height

Br: Branch number/plant; Sbr: Secondary branch number/plant

Brl: Branch length; Lno: Number of leaves/plant

GM: Green fodder yield/plant; DM : Dry matter yield/plant

L/S: Leaf-stem ratio; CP: Crude protein content (%).

The performance of other desirable accession viz. ILCT-215 (Delhi) ILCT-222 (Bihar), ILCT-228 (Rajasthan) ILCT-247 (Rajasthan), ILCT-278 (UP), ILCT-289 (UP), ILCT-295 (Maharashtra) and ILCT-298 of Rajasthan presented in Table 11.

Cataloguing and documentation

Germplasm cataloguing and documentation is essential for creating a general awareness among the plant breeders about the wealth of genetic materials and for selecting specific cultures with most desirable attributes for use in the breeding programme. Quite a few number of catalogues / PIR's (Plant Introduction Reporter's) on some economic crops have already been published by NBPGR, New Delhi and other Institutions. Cataloging and documentation is particularly important for the gene banks maintained in the different countries. The information helps better exchange of materials between the different institutes all over the world: A detail catalogue on *Clitoria ternatea* genepool was developed for the first time by providing details of origin of the materials and summary of the three years data on various plant attributes, viz. flower colour, days to flowering, plant height (cm), branch number/plant, secondary branch number/plant, branch length (cm), number of leaves/plant, green fodder yield/plant (g), dry matter yield/plant (g), leaf-stem ratio and crude protein content (Table 12).

There are various ways of characterising the materials and one of the way is identifying accessions with different grade of expression of the economic characters. In *Clitoria* five important identified agronomical attributes are ; plant height, branching, dry matter yield, leaf stem ratio and protein content. Each of the five character was grouped as low (a), medium (b) and high grades(c). A combination of different character grades yielded 70 distinct plant types. Out of these, 53 types were represented by single accession, 14 types by two accessions and three types by three accessions (Table 13).

Table 12: Characterization and cataloguing of 92 accessions of *C. ternatea*.

	1	2	3	4	5	6	7
S.No	Name of accession	Source	Flower colour	Days to flower	Plant height (cm)	Branch number /plant	Number of secondary branch /plant
1	ILCT -209	Dlh	W	46.3	65.4	11.44	12.61
2	ILCT -210	Dlh	B	46.1	60.0	11.88	14.16
3	ILCT -211	Dlh	B	46.6	91.1	10.34	12.88
4	ILCT -212	Dlh	B	46.2	68.0	10.05	14.27
5	ILCT -213	Dlh	B	43.8	88.6	13.88	15.83
6	ILCT -214	Dlh	B	46.4	89.5	13.47	15.66
7	ILCT -215	Dlh	B	43.1	86.7	15.25	15.68
8	ILCT -216	Dlh	W	46.0	88.8	14.14	17.66
9	ILCT -217	Dlh	B	43.3	84.7	10.01	16.16
10	ILCT -218	Dlh	W	46.0	67.0	11.30	13.66
11	ILCT -219	Dlh	B	46.3	85.3	11.44	16.47
12	ILCT -220	Dlh	B	44.4	81.1	12.78	12.77
13	ILCT -221	Dlh	B	47.7	85.9	13.33	18.61
14	ILCT -222	Bhr	B	47.5	94.9	11.91	18.58
15	ILCT -223	UP	B	43.7	74.3	13.37	15.11
16	ILCT -224	UP	B	46.8	85.0	14.66	15.72
17	ILCT -225	Raj	B	45.5	78.1	9.82	11.11
18	ILCT -226	Raj	B	47.6	72.7	10.10	10.05
19	ILCT -227	Raj	B	47.6	82.1	11.55	14.44
20	ILCT -228	Raj	B	44.8	84.3	14.34	16.27

(Contd..12)

(Contd..12)

	8	9	10	11	12	13
	Branch length (cm)	Number of leaves/ Plant	Green fodder yield/plant (g)	Dry matter yield/plant (g)	Leaf stem ratio	Crude protein content (%)
1	71.77	120.2	55.47	16.71	1.08	24.66
2	69.28	118.3	56.24	16.96	0.88	24.65
3	74.66	113.9	53.88	16.25	0.76	23.73
4	92.27	150.3	90.72	23.52	0.87	25.40
5	93.88	183.5	93.88	25.65	0.76	26.14
6	95.11	131.1	54.55	15.13	0.91	23.53
7	62.88	166.2	70.32	20.06	0.88	25.45
8	75.00	130.0	63.94	18.31	0.94	23.40
9	72.55	110.3	51.81	15.31	0.91	24.08
10	66.11	148.6	53.93	14.47	0.81	23.78
11	74.88	106.4	66.73	18.42	1.07	25.21
12	75.22	157.0	55.55	17.11	1.02	21.83
13	82.77	158.0	67.95	18.76	0.91	25.60
14	83.44	113.0	67.20	21.48	1.00	24.58
15	66.66	125.0	56.51	14.58	1.22	22.57
16	76.61	113.9	56.64	16.02	1.04	23.99
17	67.55	130.1	55.98	17.31	1.15	23.99
18	65.00	116.6	59.63	16.10	1.21	22.24
19	68.55	151.1	55.05	16.07	1.00	26.23
20	74.77	120.2	85.40	21.50	0.92	25.19

(Contd..12)

(Contd..12)

1		2	3	4	5	6	7
21	ILCT -229	Raj	B	41.7	78.4	10.52	16.50
22	ILCT -230	Raj	B	44.2	62.2	11.82	13.44
23	ILCT -231	MP	B	42.7	61.5	10.63	18.66
24	ILCT -232	MP	B	47.3	72.5	11.06	15.55
25	ILCT -233	MP	B	43.2	64.8	8.05	14.50
26	ILCT -234	WB	B	44.8	75.3	8.95	13.00
27	ILCT -235	Guj	B	43.6	67.4	15.31	15.77
28	ILCT -236	Guj	W	41.7	83.1	12.31	16.22
29	ILCT -237	Guj	W	43.2	56.3	15.67	14.88
30	ILCT -238	Guj	W	41.2	79.1	12.28	14.94
31	ILCT -239	UP	B	42.2	54.2	14.47	15.94
32	ILCT -240	UP	B	39.5	86.3	16.18	14.77
33	ILCT -241	UP	B	44.3	75.7	12.84	17.05
34	ILCT -242	WB	B	43.7	73.0	11.85	14.44
35	ILCT -243	UP	B	43.3	69.7	11.96	15.46
36	ILCT -244	UP	B	40.1	74.0	15.05	19.77
37	ILCT -245	UP	B	45.2	74.0	10.81	15.16
38	ILCT -246	Raj	B	42.0	71.7	11.52	19.61
39	ILCT -247	Raj	B	41.5	68.5	16.47	16.55
40	ILCT -248	Dlh	W	47.4	71.5	17.45	15.66
41	ILCT -249	Dlh	B	47.2	73.9	15.63	16.94
42	ILCT -250	Raj	B	43.0	64.8	12.55	13.00

(Contd..12)

(Contd..12)

	8	9	10	11	12	13
21	68.22	120.2	58.50	15.42	1.07	24.03
22	67.27	125.3	54.72	16.43	1.00	22.05
23	72.66	142.6	71.21	21.78	0.94	21.36
24	64.66	138.1	67.33	18.46	0.81	21.60
25	71.88	127.5	60.22	15.92	1.12	21.45
26	78.77	127.7	61.57	17.24	0.74	24.12
27	74.33	111.7	62.11	16.64	0.83	22.90
28	76.22	142.2	57.88	17.42	0.84	23.95
29	63.88	108.2	44.35	13.78	1.02	25.65
30	70.66	107.0	41.95	12.34	0.91	25.61
31	71.11	162.0	68.80	19.21	1.23	24.30
32	66.38	115.2	57.10	15.95	0.95	21.52
33	67.11	148.6	67.15	19.01	0.94	26.05
34	69.22	118.5	49.25	14.61	1.22	21.44
35	79.44	162.2	62.81	18.47	1.06	24.35
36	79.44	162.0	74.62	21.90	0.92	21.96
37	69.33	122.9	52.00	14.36	1.13	23.36
38	89.11	159.3	58.22	18.32	0.75	24.75
39	86.44	157.7	57.40	17.97	1.06	25.32
40	67.44	169.4	70.58	21.94	1.15	20.31
41	70.33	168.0	63.90	17.04	1.04	26.04
42	63.00	127.4	44.28	11.70	1.13	25.59

(Contd..12)

(Contd..12)

	1	2	3	4	5	6	7
43	ILCT -251	Raj	B	44.7	74.1	10.86	11.70
44	ILCT -252	Raj	B	48.0	67.6	9.21	17.20
45	ILCT -253	Raj	B	44.2	71.9	16.86	13.55
46	ILCT -254	Raj	B	45.5	78.4	10.34	18.00
47	ILCT -255	Raj	WB	44.2	64.0	10.12	17.88
48	ILCT -256	Raj	B	43.1	59.5	11.51	13.27
49	ILCT -257	Raj	B	44.2	58.6	9.94	16.16
50	ILCT -258	Raj	B	49.6	68.7	13.93	17.44
51	ILCT -259	Raj	B	44.1	65.9	14.30	14.88
52	ILCT -260	Raj	B	46.1	71.1	13.16	19.88
53	ILCT -261	TN	B	46.2	89.0	11.82	20.27
54	ILCT -262	UP	B	49.4	74.6	11.44	16.83
55	ILCT -263	UP	B	45.7	58.7	11.15	12.55
56	ILCT -264	UP	B	48.2	77.8	12.66	15.77
57	ILCT -265	UP	B	46.7	66.8	13.88	17.05
58	ILCT -266	UP	B	45.5	59.4	9.66	14.72
59	ILCT -267	Raj	B	45.5	62.0	12.30	13.05
60	ILCT -268	Raj	B	46.2	65.6	16.60	17.83
61	ILCT -269	Raj	B	45.4	71.9	11.35	24.83
62	ILCT -270	Raj	B	39.6	70.8	13.40	14.83
63	ILCT -271	Raj	B	39.58	63.8	13.40	17.22
64	ILCT -272	Raj	B	44.3	69.2	17.94	23.00

(Contd..12)

(Contd..12)

	8	9	10	11	12	13
43	71.44	123.5	60.22	17.22	1.01	23.04
44	67.00	122.2	52.11	15.93	1.24	22.14
45	67.77	99.8	39.32	11.32	0.91	22.12
46	67.88	178.7	74.17	21.32	1.07	22.14
47	64.22	133.9	48.22	13.85	1.10	24.50
48	62.22	120.9	42.27	12.65	0.89	22.80
49	60.00	134.5	65.92	19.62	1.00	23.85
50	62.77	135.4	44.46	13.34	0.97	24.19
51	59.77	115.3	51.76	13.77	0.84	22.23
52	67.22	120.5	41.80	12.65	1.07	23.42
53	85.44	154.4	75.04	22.48	0.87	23.78
54	69.11	145.6	53.34	16.91	0.81	25.72
55	54.11	109.9	39.43	11.12	0.90	22.92
56	79.50	118.7	56.91	17.25	0.78	24.52
57	63.11	138.2	66.53	20.30	1.01	24.37
58	62.11	109.6	46.35	13.72	0.99	22.46
59	56.55	96.6	43.82	13.16	0.91	26.99
60	65.66	121.1	47.98	12.84	1.03	26.15
61	94.22	156.9	86.05	24.08	0.83	25.67
62	72.44	120.5	64.81	19.03	0.87	25.02
63	64.55	157.3	83.36	24.55	0.81	26.54
64	72.00	154.3	78.22	23.11	0.86	21.72

(Contd..12)

(Contd..12)

	1	2	3	4	5	6	7
65	ILCT -273	Raj	B	43.7	67.7	12.80	19.27
66	ILCT -274	Raj	B	43.3	66.9	9.57	13.16
67	ILCT -275	Raj	B	40.1	58.9	9.71	18.22
68	ILCT -276	Raj	B	45.2	57.0	9.54	15.33
69	ILCT -277	UP	B	42.0	71.2	11.43	20.16
70	ILCT -278	UP	B	41.5	64.6	15.95	17.33
71	ILCT -279	UP	B	47.4	70.3	12.74	19.00
72	ILCT -280	Up	B	47.2	72.0	10.63	12.55
73	ILCT -281	UP	B	43.0	65.9	10.40	12.94
74	ILCT -282	MP	WB	44.7	71.9	9.92	15.61
75	ILCT -283	MP	B	48.0	70.0	11.26	19.27
76	ILCT -284	MP	LB	44.2	71.6	9.18	17.22
77	ILCT -285	MP	LB	45.5	69.4	9.92	14.50
78	ILCT -286	MP	B	44.2	67.5	13.56	13.11
79	ILCT -287	MP	B	43.1	68.7	11.85	14.77
80	ILCT -288	UP	B	44.2	63.6	11.67	13.38
81	ILCT -289	UP	B	49.6	74.5	12.67	15.50
82	ILCT -290	UP	B	44.1	68.6	12.47	20.50
83	ILCT -291	Guj	B	46.1	69.7	11.51	14.58
84	ILCT -292	Guj	B	46.2	66.4	12.88	17.66
85	ILCT -293	Guj	W	49.4	63.01	9.82	18.38
86	ILCT -294	MST	PW	45.7	68.3	10.07	16.00

(Contd..12)

(Contd..12)

	8	9	10	11	12	13
65	75.44	113.9	52.37	15.01	0.86	25.39
66	68.77	102.3	61.33	19.20	0.95	20.75
67	62.44	103.2	55.13	12.71	0.64	25.54
68	60.22	106.3	45.13	11.74	0.90	20.13
69	65.77	153.2	69.76	19.70	0.65	23.54
70	72.33	132.7	81.38	22.30	0.78	25.78
71	66.77	153.1	75.22	21.00	0.78	21.50
72	77.88	120.6	51.28	13.94	0.75	24.11
73	66:22	115.4	51.87	14.27	0.70	22.21
74	73.55	91.0	41.70	11.01	0.71	26.57
75	81.55	114.5	64.77	19.01	0.87	21.63
76	74.66	94.6	51.00	15.00	0.97	22.65
77	66.66	96.6	43.77	12.11	1.09	25.01
78	61.33	103.2	63.51	18.85	0.97	22.69
79	76.55	90.2	42.06	11.77	1.17	22.07
80	60.00	125.9	74.02	20.85	1.09	23.74
81	85.16	143.0	90.80	26.42	0.98	23.89
82	70.77	143.9	55.32	15.47	0.95	25.85
83	64.11	111.5	46.51	12.04	0.72	23.11
84	70.00	178.3	77.88	21.97	0.72	23.37
85	58.00	116.6	51.55	13.68	1.07	23.20
86	67.22	108.6	56.06	15.58	0.89	25.45

(Contd..12)

(Contd..12)

	1	2	3	4	5	6	7
87	ILCT -295	MST	B	48.2	76.9	13.67	18.66
88	ILCT -296	MST	B	46.7	77.4	10.45	14.83
89	ILCt -297	MST	W	45.5	53.2	12.18	19.66
90	ILCT -298	Raj	B	45.5	71.1	12.92	20.94
91	ILCT -299	TN	B	48.0	77.9	14.46	19.11
92	ILCT -300	Bhr	W	42.6	64.6	15.80	19.27

(Contd..)

(Contd..12)

	1	2	3	4	5	6
87	80.33	170.5	97.73	26.66	0.97	22.57
88	57.77	136.2	68.94	20.51	0.96	26.44
89	70.11	127.6	57.45	16.80	1.00	24.50
90	68.88	153.4	86.62	23.74	1.03	23.02
91	73..33	139.1	66.14	18.53	0.91	25.41
92	84.84	108.0	56.51	17.48	0.72	23.32

Scheme of classification may be summarised as;

Characters	Class	Range
1a	Dwarf	53.25 - 67.13
1b	Medium	67.14 - 81.02
1c	Tall	81.03 - 94.90
2a	Low branches	8.05 - 11.34
2b	Medium branches	11.35 - 14.64
2c	Highly branched	14.65 - 17.94
3a	Low dry matter	11.01 - 16.20
3b	Medium dry matter	16.21 - 21.39
3c	High dry matter	21.40 - 26.60
4a	Low L/S ratio	0.64 - 0.83
4b	Medium L/S ratio	0.84 - 1.04
4c	High L/S ratio	1.05 - 1.24
5a	Low CP content	21.13 - 22.41
5b	Medium CP contents	22.42 - 24.61
5c	High CP contents	24.62 - 26.99

1 : Plant height (cm) 2: Number of branches/plant
3 : Dry matter/plant (g) 4: Leaf-stem ratio
5 : Crude protein content (%).

Factors affecting the germination of *Clitoria* seeds.

The germination behaviour of leguminous seeds is determined by the extent of hard-seededness, dormancy and polymorphism. In the present study eight diverse genotypes (with different seed coat colours) were examined for germination behaviour under different treatments viz. sowing depths (cm), soils types , temperature (°C) and different colour of light. The results obtained are as follows :

(I) Effect of different sowing depths(cm).

The results revealed significantly higher germination rate at 2 cm sowing depth than sowing at greater depths (Table 14). In general the germination decreased from a maximum of 72.5% at 2 cm depth to 35% at 8 cm depth. Differential genotypic response was found to the sowing depths on seed germination. Bluish grey colour seeds of ILCT-221 and ILCT-249 with 91.3 and 76.2% germination, respectively, at 2 cm depth showed relatively

Table 13: A Key for the classification of *C. ternatea* genepool.

Groups	Characters	Performance for various characters and respective accessions.
	1a	Dwarf plants
	2a	Low number of branches
	3a	Low dry matter per plant
	4a	Low leaf-stem ratio
	5a	Low crude protein content
01		(ILCT -281)
	5b	Medium crude protein content
02		(ILCT -218)
	5c	High crude protein content
03		(ILCT -275)
	4b	Medium leaf-stem ratio
	5a	Low crude protein content
04		(ILCT -276)
	5b	Medium crude protein content
05		(ILCT -263 and 266)
	4c	High leaf-stem ratio
	5a	Low crude protein content
06		(ILCT -233)
	5b	Medium crude protein content
07		(ILCT -255 and 293)
	3b	Medium dry matter per plant
	4b	Low leaf-stem ratio
	5a	Low crude protein content
08		(ILCT -274)
	5b	Medium crude protein content
09		(ILCT -257)
	3c	High dry matter per plant
	4b	Medium leaf-stem ratio
	5a	Low crude protein content
10		(ILCT -231)
	2b	Medium number of branches

(Contd..13)

(Contd..13)

1	2	3
	3a	Low dry matter per plant
	4b	Medium leaf-stem ratio
	5a	Low crude protein content
11		(<u>ILCT -259</u>)
	5b	Medium crude protein content
12		(<u>ILCT -256</u>)
	4c	High leaf-stem ratio
	5c	High crude protein content
13		(<u>ILCT -250</u>)
	3b	Medium dry matter per plant
	4b	Medium leaf-stem ratio
	5a	Low crude protein content
14		(<u>ILCT -230</u>)
	5b	Medium crude protein content
15		(<u>ILCT -265</u> and <u>297</u>)
	5c	High crude protein content
16		(<u>ILCT -210</u>)
	4c	High leaf-stem ratio
	5b	Medium crude protein content
17		(<u>ILCT -239</u> and <u>288</u>)
	5c	High crude protein content
18		(<u>ILCT -209</u>)
	3c	High dry matter per plant
	4a	Low leaf-stem ratio
	5b	Medium crude protein content
19		(<u>ILCT -292</u>)
	5c	High crude protein content
20		(<u>ILCT -271</u>)
	2c	Tall plants
	3a	Low dry matter per plant
	4b	Medium leaf-stem ratio
	5c	High crude protein content
21		(<u>ILCT -237</u> and <u>268</u>)

(Contd..13)

1	2	3
	3b	Medium dry matter per plant
	4a	Low leaf-stem ratio
	5b	Medium crude protein content
22		(ILCT -300)
	3c	High dry matter per plant
	4a	Low leaf-stem ratio
	5c	High crude protein content
23		(ILCT -278)
	1b	Medium plant height
	2a	Low number of branches
	3a	Low dry matter per plant
	4a	Low leaf stem ratio
	5b	Medium crude protein content
24		(ILCT -280)
	5c	High crude protein content
25		(ILCT -282)
	4b	Medium leaf-stem ratio
	5b	Medium crude protein content
26		(ILCT -284)
	5c	High crude protein content
27		(ILCT -294)
	4c	High leaf-stem ratio
	5a	Low crude protein content
28		(ILCT -226 and 252)
	5b	Medium crude protein content
29		(ILCT -229 and 245)
	5c	High crude protein content
30		(ILCT -285)
	3b	Medium dry matter per plant
	4a	Low leaf-stem ratio
	5a	Low crude protein content
31		(ILCT -232)
	5c	High crude protein content
32		(ILCT -234)

(Contd..13)

(Contd..13)

1	2	3
	4b	Medium leaf-stem ratio
	5a	Low crude protein content
33		(ILCT -283)
	5b	Medium crude protein content
34		(ILCT -251)
	4c	High leaf-stem ratio
	5a	Low crude protein content
35		(ILCT -254)
	5b	Medium crude protein content
36		(ILCT -225)
	3c	High dry matter per plant
	4a	Low leaf-stem ratio
	5c	High crude protein content
37		(ILCT -269)
	4b	Medium leaf-stem ratio
	5c	High crude protein content
38		(ILCT -212 and 296)
	2b	Medium number of branches
	3a	Low dry matter per plant
	4a	Low leaf-stem ratio
	5b	Medium crude protein content
39		(ILCT -291)
	4b	Medium leaf-stem ratio
	5b	Medium crude protein content
40		(ILCT -258)
	5c	High crude protein content
41		(ILCT -238, 273 and 290)
	4c	High leaf-stem ratio
	5a	Low crude protein content
42		(ILCT -287)
	5b	Medium crude protein content
43		(ILCT -242 and 260)

(Contd..13)

(Contd..13)

1	2	3
44	5c	High crude protein content (ILCT -223)
45	3b 4a 5a	Medium dry matter per plant Low leaf-stem ratio Low crude protein content (ILCT -279)
46	5b	Medium crude protein content (ILCT -264 and 277)
47	5c	High crude protein content (ILCT -246 and 262)
48	4b 5b	Medium leaf-stem ratio Medium crude protein content (ILCT -286)
49	5c	High crude protein content (ILCT-241, 270 and 299)
50	4c 5b	High leaf-stem ratio Medium crude protein content (ILCT -243)
51	3c 4b 5b	High dry matter per plant Medium leaf-stem ratio Medium crude protein content (ILCT -289, 295 and 298)
52	2c 3a 4b 5a	High number of branches Low dry matter per plant. Medium leaf-stem ratio Low crude protein content (ILCT 253)
53	3b 4a 5b	Medium dry matter per plant Low leaf-stem ratio Medium crude protein content (ILCT -235)
54	4c 5c	High leaf-stem ratio High crude protein content (ILCT -247 and 249)

(Contd..13)

(Contd..13)

1	2	3
	3c	High dry matter per plant
	4b	Medium leaf-stem ratio
	5a	Low crude protein content
55		(ILCT -244 and 272)
	4c	High leaf-stem ratio
	5a	Low crude protein content
56		(ILCT -248)
	1c	Tall plants
	2a	Low number of branches
	3a	Low dry matter per plant
	4b	Medium leaf-stem ratio
	5b	Medium crude protein content
57		(ILCT -217)
	3b	Medium dry matter per plant
	4a	Lowleaf-stem ratio
	5b	Medium crude protein content
58		(ILCT -211)
	2b	Medium number of branches
	3a	Low dry matter per plant
	4b	Medium leaf stem ratio
	5b	Medium crude protein content
59		(ILCT -214)
	5c	High crude protein content
60		(ILCT -227)
	3b	Medium dry matter per plant
	4b	Medium leaf-stem ratio
	5a	Low crude protein content
61		(ILCT -220)
	5b	Medium crude protein content
62		(ILCT -216 and 236)
	5c	High crude protein content
63		(ILCT -221)
	4c	High leaf-stem ratio
	5c	High crude protein content
64		(ILCT -219)

(Contd..13)

(Contd..13)

1	2	3
	3c	High dry matter per plant
	4a	Low leaf-stem ratio
	5c	High crude protein content
65		(ILCT -213)
	4b	Medium leaf-stem ratio
	5b	Medium crude-protein content
66		(ILCT -222 and 261)
	5c	High crude protein content
67		(ILCT -228)
	2c	High number of branches
	3a	Low dry matter per plant
	4b	Medium leaf-stem ratio
	5a	Low crude protein content
68		(ILCT -240)
	5b	Medium crude protein content
69		(ILCT -224)
	3b	Medium dry matter per plant
	4b	Medium leaf-stem ratio
	5c	High crude protein content
70		(ILCT -215)

higher germination than other seed types. Lowest emergence was observed in brown seeded genotype ILCT-269 (54%). Black seeded genotype ILCT-272 proved superior over other types when sown at 4 cm (73.5%) and 6 cm depth (60.3%) while in ILCT-249 (bluish grey seed) the germination was lowest amongst all the types at 4 and 6 cm depth.. At deep (8cm) sowing grey seeded genotypes ILCT-213 and ILCT-215 showed highest germination (46.6 and 44.3%) while in the bluish grey genotype (ILCT-221) it was the lowest (22.2%).

(II) Effect of different soil types

The germination of different types of Clitoria seeds varied significantly with different types of soil (Table 15). The mixed soil type was most conducive to seed germination (72.9%) followed by organic (63.8%) and red soils (63.3%) and minimum (58.4%) in black soils (Table 15). All the genotypes showed similar trend of germination (55-69 %) in red soil treatment. In black soil, brown and grey seeded accessions viz. ILCT-213 and ILCT-269 showed relatively higher percentage germination (66.8%) than other types. Under organic soils treatments, significantly higher number of seeds germinated (78.3%) in black seeded genotype ILCT 272 followed by ILCT-261 of brown seed coat. Among all the treatment, mixed soils proved to be most suitable for the germination of *Clitoria* seeds, the maximum being 88.8% germination in grey seeded genotype ILCT-213 followed by 85.3% in black seeded ILCT-278.

(III) Effect of different temperatures (°c)

Germination of various seed types of *C. ternatea* was highly significantly influenced due to temperature treatments (Table 16). The average germination of different types of seed increased progressively from 33.6% at 5°c to 71.0% at 35°c. The varietal response to temperature was also highly significant. It ranged between 22% to 44% at low temperatures and between 52% to 83% at higher temperatures. At low temperature (5°c) poorest germination was observed in brown seeded ILCT 269 (22.2%) followed by bluish grey ILCT 249 (25.7%). At more than 15°c maximum germinability (83.4%) was observed in bluish grey seeded ILCT 249 followed by 79.4% in brown seeded ILCT 269 (Table 16). Although strong temperature effects on seed germination were pronounced between 5° to 15°c, these differences were much less between 15 to 35° in the different seed types. Amongst all the seed types brown seeded ILCT 261 was conspicuous in the sense that it showed relatively higher germination (44%) at the lowest temperature and lower germination (52-53%) at more than 15°c as compared to other genotypes.

(IV) Effect of different colours of light

The germination of various genotypes of *Clitoria* varied with different colour of

Table 14: Effect of different sowing depths (cm) on germination of *C. ternatea* genotypes.

Genotypes	Seed colour	% seed germination at D1 (2cm)	D2 (4cm)	D3 (6cm)	D4 (8cm)
ILCT -213	Grey	59.01[a] (73.5)[b]	58.34 (72.4)	48.18 (55.4)	43.06 (46.6)
ILCT -215	Grey	57.61 (71.0)	50.79 (60.1)	48.20 (55.5)	41.73 (44.3)
ILCT -221	Bluish grey	72.84 (91.3)	47.24 (53.9)	36.57 (35.5)	28.06 (22.2)
ILCT -249	Bluish grey	60.70 (76.2)	43.08 (46.0)	33.84 (31.0)	36.51 (35.4)
ILCT -261	Brown	53.49 (64.0)	45.61 (51.0)	44.84 (48.8)	35.17 (33.2)
ILCT -269	Brown	48.33 (54.0)	46.90 (53.3)	43.08 (46.6)	40.33 (41.8)
ILCT -272	Black	57.49 (71.2)	59.01 (73.5)	50.94 (60.3)	37.84 (37.6)
ILCT -278	Black	57.61 (71.0)	48.51 (57.8)	48.21 (55.6)	30.56 (25.8)
	Mean	58.38 (72.5)	50.06 (58.8)	44.23 (48.5)	36.65 (35.86)

Interaction due to	SE(m)±	CD at 5%	\`F'Value	CV(%)
Sowing depth	0.50	1.39	297.20**	17.70
Genotypes	0.71	1.79	11.37**	
Genotypes X Sowing depth	1.42	3.93	10.81**	

a Sign inverse transformed value
b Actual germination percentage values are given in parenthesis
* $P < 0.05$
** $P < 0.01$

Table 15: Effect of different soil types and their combination on germination of *C. ternatea* genotypes

Genotypes	Seed colour	% seed germination in			
		Red soil	Black soil	Organic soil	Mixed soil
ILCT -213	Grey	53.48[a] (64.6)[b]	54.79 (66.8)	48.18 (55.5)	70.47 (88.8)
ILCT -215	Grey	56.18 (69.0)	49.49 (57.8)	54.12 (65.63)	54.79 (66.7)
ILCT -221	Bluish grey	52.08 (62.3)	45.64 (57.1)	49.51 (57.8)	53.49 (62.6)
ILCT -249	Bluish grey	53.49 (64.6)	46.90 (53.3)	52.08 (62.3)	56.69 (69.8)
ILCT -261	Brown	48.09 (55.4)	46.90 (53.3)	56.40 (69.4)	59.01 (73.4)
ILCT -269	Brown	53.49 (64.6)	54.79 (66.8)	53.48 (64.6)	56.18 (69.0)
ILCT -272	Black	50.79 (60.1)	48.18 (55.5)	62.22 (78.3)	60.70 (76.1)
ILCT -278	Black	53.49 (64.6)	52.10 (62.3)	48.18 (55.5)	67.47 (85.3)
	Mean	52.63 (63.15)	49.84 (58.40)	53.02 (63.80)	58.60 (72.90)

Interaction due to	SE (m)±	CD at 5%	'F' Value	CV(%)
Soil type	0.55	1.51	91.11**	17.66
Genotypes	0.77	2.14	2.29**	
Genotypes X Soil types	1.54	4.28	4.94**	

a Sign inverse transformed value
b Actual germination percentage values are given in parenthesis
** $P < 0.01$

Table 16: Effect of different temperatures (^{o}C) on germination of *C. ternatea* genotypes

Genotypes	Seed colour	% seed germination			
		Temp. $5^{o}C$	Temp. $15^{o}C$	Temp. $25^{o}C$	Temp. $35^{o}C$
ILCT -213	Grey	36.56[a] (35.5)[b]	53.20 (64.1)	60.72 (76.1)	56.71 (69.9)
ILCT -215	Grey	35.17 (33.2)	56.58 (69.7)	58.50 (72.7)	56.86 (70.1)
ILCT -221	Bluish grey	33.84 (31.0)	59.01 (73.5)	57.28 (70.8)	57.56 (71.2)
ILCT -249	Bluish grey	30.50 (25.7)	60.88 (76.3)	59.07 (73.6)	65.96 (83.4)
ILCT -261	Brown	41.73 (44.3)	46.15 (52.0)	46.16 (52.0)	46.92 (53.3)
ILCT -269	Brown	28.06 (22.2)	57.22 (70.7)	58.29 (72.4)	63.03 (79.4)
ILCT -272	Black	36.57 (35.5)	56.38 (69.0)	55.58 (68.1)	53.30 (64.3)
ILCT -278	Black	40.33 (41.8)	59.08 (73.6)	58.09 (72.0)	59.22 (73.8)
	Mean	35.34 (33.65)	56.08 (68.8)	56.71 (69.9)	57.44 (71.0)

Interaction due to	SE (m) ±	CD at 5%	'F' value	CV(%)
Temperature	0.40	1.11	107.22**	19.4
Genotypes	0.66	1.82	26.46**	
Genotypes X Temperature	1.41	3.15	7.80**	

a Sign inverse transformed value
b Actual germination percentage values are given in parenthesis
** $P < 0.01$

Table 17: Effect of different colour of light on germination of *C. ternatea* genotypes.

Genotypes	Seed colour	% seed germination in Blue	Violet	Red	Dark Black
ILCT -213	Grey	54.12[a] (65.5)[b]	53.98 (65.4)	51.59 (61.2)	59.01 (73.5)
ILCT -215	Grey	50.78 (60.0)	58.09 (72.1)	56.68 (69.8)	57.49 (71.2)
ILCT -221	Bluish grey	46.16 (52.1)	53.18 (64.1)	55.58 (68.0)	60.70 (76.2)
ILCT -249	Bluish grey	52.38 (62.7)	53.94 (65.3)	59.88 (74.8)	56.18 (69.0)
ILCT -261	Brown	46.15 (52.0)	46.91 (53.3)	45.38 (50.7)	53.49 (64.0)
ILCT -269	Brown	53.98 (65.4)	54.99 (66.7)	62.82 (79.1)	48.20 (55.5)
ILCT -272	Black	54.89 (66.9)	54.77 (66.7)	53.30 (64.3)	62.82 (79.1)
ILCT -278	Black	52.44 (62.8)	56.46 (69.5)	59.01 (43.5)	57.61 (71.0)
	Mean	53.36 (61.0)	54.01 (65.5)	55.53 (68.0)	56.93 (69.9)

Interaction due to	SE(m) ±	CD at 5%	`F' value	CV(%)
Light colour	0.37	1.02	12.33**	12.10
Genotypes	0.60	1.66	25.94**	
Genotypes X Light colours	1.04	2.88	5.22**	

a Sign inverse transformed value
b Actual germination percentage values are given in parenthesis
** $P < 0.01$

light exposure to seed. Seed germination was significantly higher (69.9%) in total darkness while it was lowest under blue colour of light (Table 17). The brown seeded ILCT 261 showed lowest germination in all the light treatments except under dark situations and another brown seeded ILCT-269 showed minimum emergence (55.5%) in total darkness. Maximum germination was recorded in black seeded genotype ILCT-272 under blue (66.9%) and dark situation (79.1%). Further, the grey seeded genotype ILCT-215 showed maximum germination in violet light while brown seeded ILCT-269 gave highest germination (79.1%) in red colour of light.

Genotypic stability

Analysis of variance (ANOVA) for gene *X* environment interaction (Table-18) indicated that the varietal differences were significant for dry matter (DMY t/h), crude protein yield (CP t/h) and dry matter/plant (g). Environment *X* varieties were found to be significant for all the traits except for green fodder yield (GFY t/h), leaf-stem ratio and dry matter/plant (g). These results indicated strong environmental influence on the expression of genetic variability. It is confirmed by the significant mean sum of squares due to environment observed for the characters except for dry matter per plant (g). Varieties *X* environment interaction were found to be significant for crude protein yield (t/h) and plant height (cm) only. It showed that the improvement in the varieties in relation to these two characters only may be possible for particular environment (s).

Variances due to environment (linear) were significant for all the characters except for leaf-stem ratio. It indicated that the positive swift in the environmental conditions may bring about promising genotypes for different attributes. Varieties X environment linear were significant for dry matter yield (t/h), crude protein yield (t/h), plant height (cm) and dry matter per plant (g) which indicated possibility of prediction of performance of genotypes for given environment. Pooled deviations were significant for dry matter yield (DMY t/h), crude protein yield (t/h), branch number per plant, green fodder/plant (g) and dry matter per plant (g). Out of these characters the significant variances for varieties X environment linear and pooled deviation were found to be common for dry matter yield (t/h), crude protein yield (t/h) and dry matter/ plant (g). A definite conclusion for prediction of performance for the genotypes for these parameters therefore may hardly be drawn. The prediction of performance of the varieties for branch number and green fodder/plant (g) may not be possible at all.

Results for stability parameters indicated that 50% of the varieties performed below the over all mean for green fodder yield (t/h). Two genotypes namely ILCT-278 and ILCT-249 showed an increased fodder production potential, value of 'bi' to be 0.51 and 1.317, respectively, while showing less deviation from unity. The mean square deviation of these

Table 18: ANOVA for G X E interaction for fodder, crude protein, seed yield and forage yield components in C. ternatea genotypes.

Source of Variation	df	MS Y1	MS Y2	MS Y3	MS Y4	MS X1	MS X2	MS X3	MS X4	MS X5
Varieties	7	4.373	0.839**	0.036**	0.023**	80.525	3.982	122.439	14.520	0.026
Environment x Variety	16	13.174	1.226**	0.055	0.0004	130.925**	24.058**	461.700**	45.904**	0.013
Environment	2	94.887	9.045**	0.402**	0.001	838.664**	148.000**	2073.568**	289.347**	0.017*
Varieties x Environment	14	1.501	0.109	0.006*	0.0003	29.819**	6.352	1020.862	11.127	0.125
Environment Linear	1	189.774**	18.091**	0.804**	0.002**	1677.328**	296.000**	5947.137	578.694**	0.035
Varieties x Environment	7	1.889	0.169**	0.009**	0.0003	55.181**	6.283	141.767	17.063**	0.015
Pooled Deviation	8	0.974	0.042*	0.003**	0.0003	3.900	5.618**	55.963**	4.542*	0.008
Pooled Error	48	0.209	0.019	0.001	0.0004	6.936	0.743	14.688	1.677	0.008
Total	23	10.496	1.108	0.049	0.007	115.586	17.948	358.447	36.353	0.017

Y1 Green fodder yield (t/h)

Y2 Dry matter yield (t/h)

Y3 Crude protein yield (t/h)

Y4 Seed yield (t/h)

X1 Plant height (cm)

X2 Branch number

X3 Fodder yield/plant (g)

X4 Dry matter yield/plant (g)

X5 Leaf/stem ratio

Table 19: Stability parameters of individual genotypes in C.ternatea

Varieties		Green fodder yield (t/h)	Dry fodder yield (t/h)	Crude protein (t/h)	Seed yield (t/h)	Plant height (cm)	Branch number	Green fodder /plant (g)	Dry matter /plant (g)	L/S ratio
ILCT-213	Mean	16.57	4.72	1.09	0.36	74.34	12.37	72.54	20.78	1.33
	bi	0.960	0.812	0.719	2.509	1.394	0.557	0.808	0.770	-1.160
	s^2di	-0.174	-0.007	0.000	-0.001	2.906	-0.731	2.672	3.054	-0.008
ILCT-215	Mean	18.21	5.29	1.10	0.28	66.62	15.67	56.98	15.92	1.44
	bi	1.439	1.342	1.377	0.313	0.475	1.422	0.273	0.252	2.600
	s^2di	0.667*	0.002	-0.002	-0.001	-4.672	-0.706	84.767*	5.371	-0.008
ILCT-221	Mean	18.38	4.15	1.09	0.49	67.52	14.06	65.45	18.68	1.50
	bi	1.160	0.892	0.838	-0.157	1.141	0.718	0.814	0.561	1.469
	s^2di	3.041**	0.100*	0.009*	-0.001	-4.584	1.740	169.022**	8.883*	-0.005
ILCT-249	Mean	18.70	5.85	1.22	0.35	75.36	13.80	71.27	22.00	1.30
	bi	1.317	1.464	1.283	1.254	0.784	0.564	1.259	1.262	0.478
	s^2di	-0.067	-0.019	0.001	-0.001	-6.832	6.795**	78.530**	7.288**	0.009

(contd..19)

(Contd..19)

1		2	3	4	5	6	7	8	9	10
ILCT-261	Mean	15.50	4.51	0.87	0.29	73.00	15.06	77.61	22.30	1.40
	bi	0.761	0.821	0.795	0.956	1.114	1.629	1.285	1.352	0.872
	s^2di	0.146	-0.017	0.000	-0.000	6.504	20.658**	-14.677	- 1.674	0.019
ILCT-269	Mean	16.95	5.21	1.02	0.29	80.46	13.67	74.11	22.27	1.54
	bi	0.656	0.902	1.067	-0.157	1.958	0.726	1.652	1.725	4.202
	s^2di	-0.031	-0.018	-0.001	-0.001	-6.493	3.123	6.158	1.192	-0.008
ILCT-272	Mean	16.59	4.59	0.98	0.51	70.56	15.83	73.58	20.10	1.51
	bi	0.756	0.685	0.585	2.495	0.710	1.195	1.234	1.28	-1.471
	s^2di	2.711**	0.98*	0.000	0.002	-6.572	7.293**	-14.276	-1.255	-0.007
ILCT-278	Mean	18.72	5.89	1.17	0.38	65.03	14.70	69.98	21.38	1.54
	bi	0.951	1.081	1.335	0.782	0.424	1.190	0.674	0.790	1.010
	s^2di	-0.169	0.053	0.002	-0.001	8.468	0.827	17.993	0.062	0.009

Stability parameters (bi & s^2di) for GFY (t/h) in the genotypes of *C.ternatea*

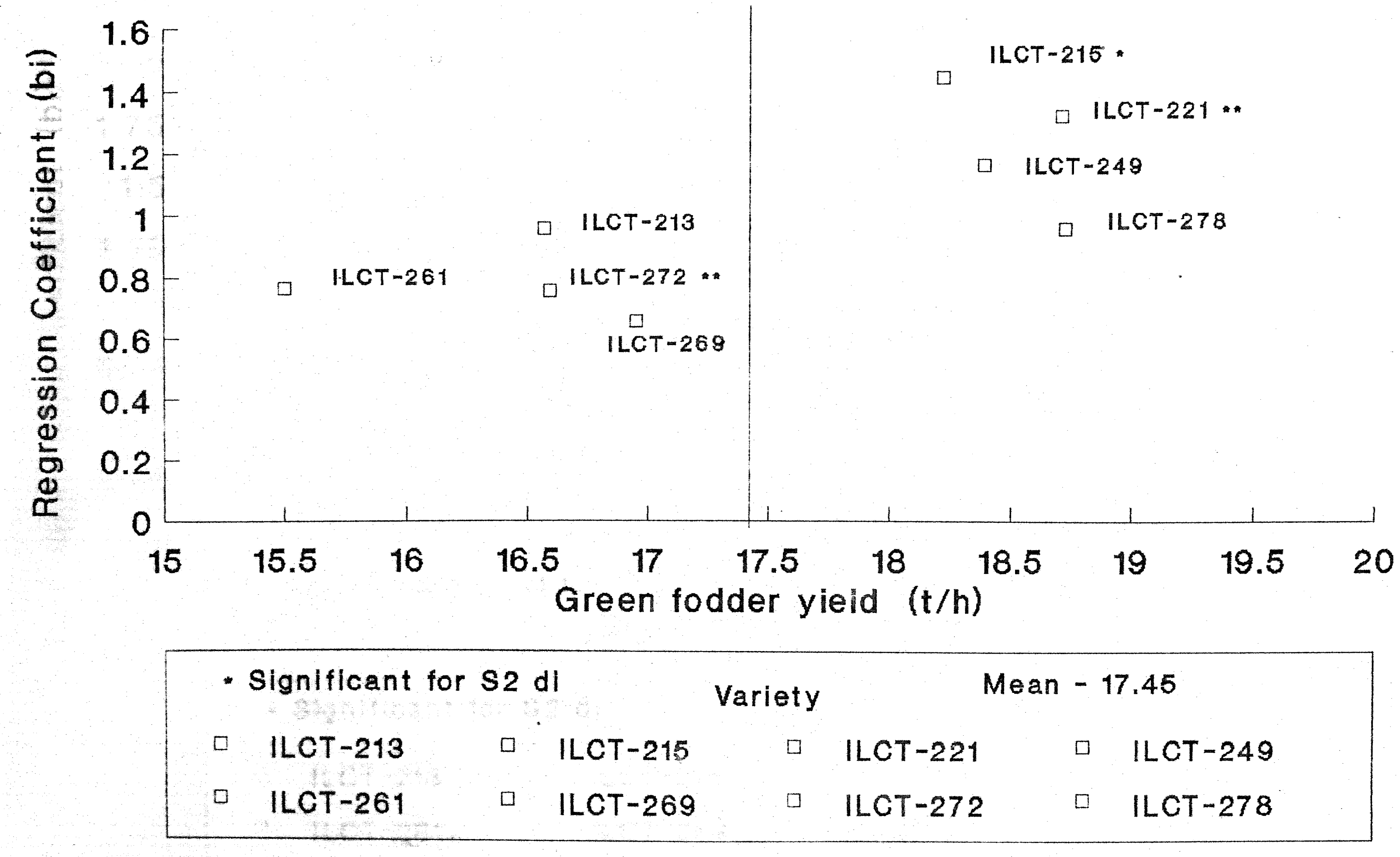


Figure - 6

Stability parameters (bi & S^2di) for DFY (t/h) in the genotypes of *C. ternatea*

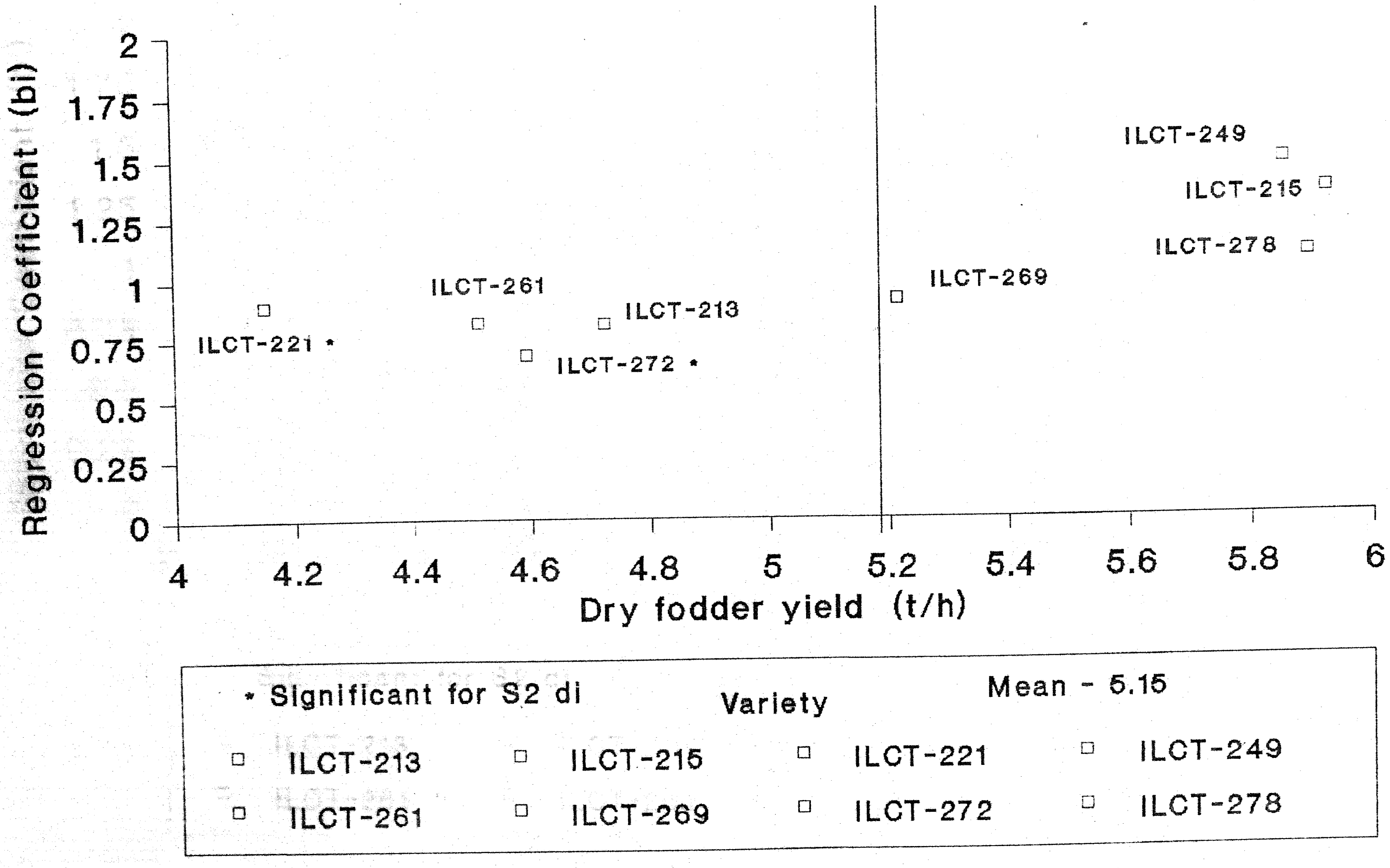


Figure - 7

Stability parameters (bi & S^2di) for CP yield (t/h) in the genotypes of *C. ternatea*

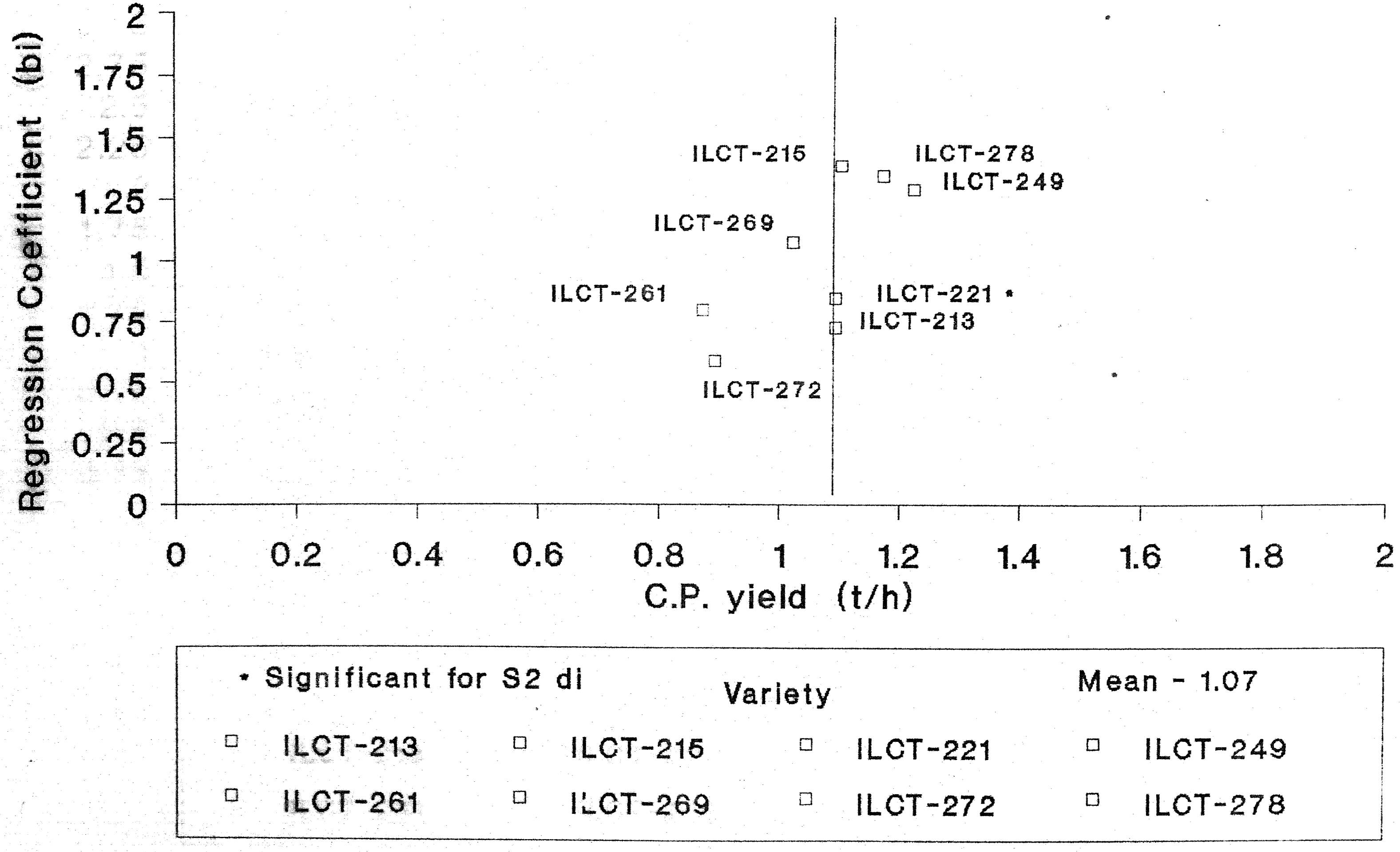


Figure - 8

Stability parameters (bi & S^2di) for seed yield (t/h) in the genotypes of *C. ternatea*

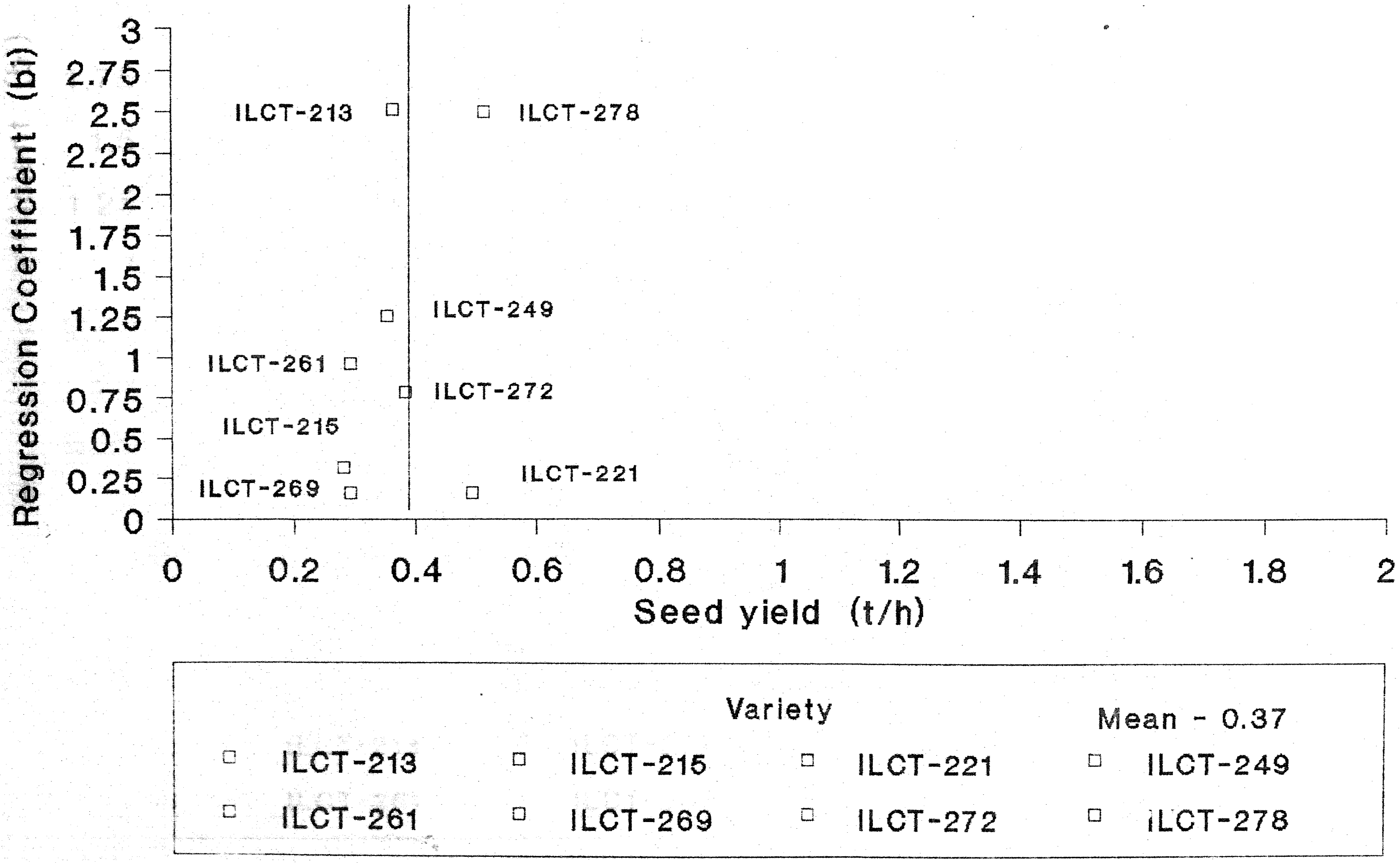


Figure - 9

Stability parameters (bi & S^2di) for plant height (cm) in the genotypes of *C. ternatea*

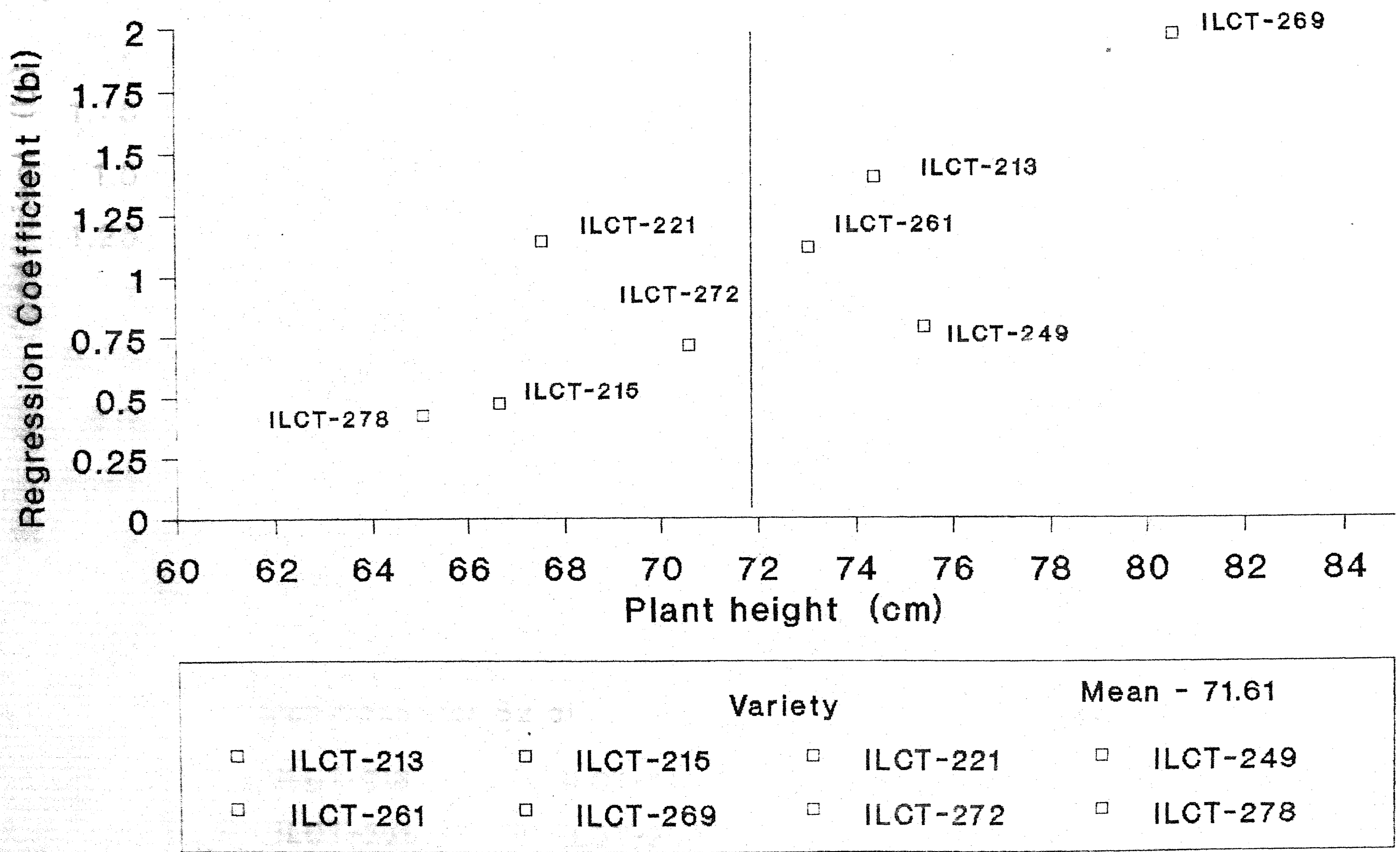


Figure - 10

Stability parameters (bi & S^2di) for branch number /plant in the genotypes of *C. ternatea*

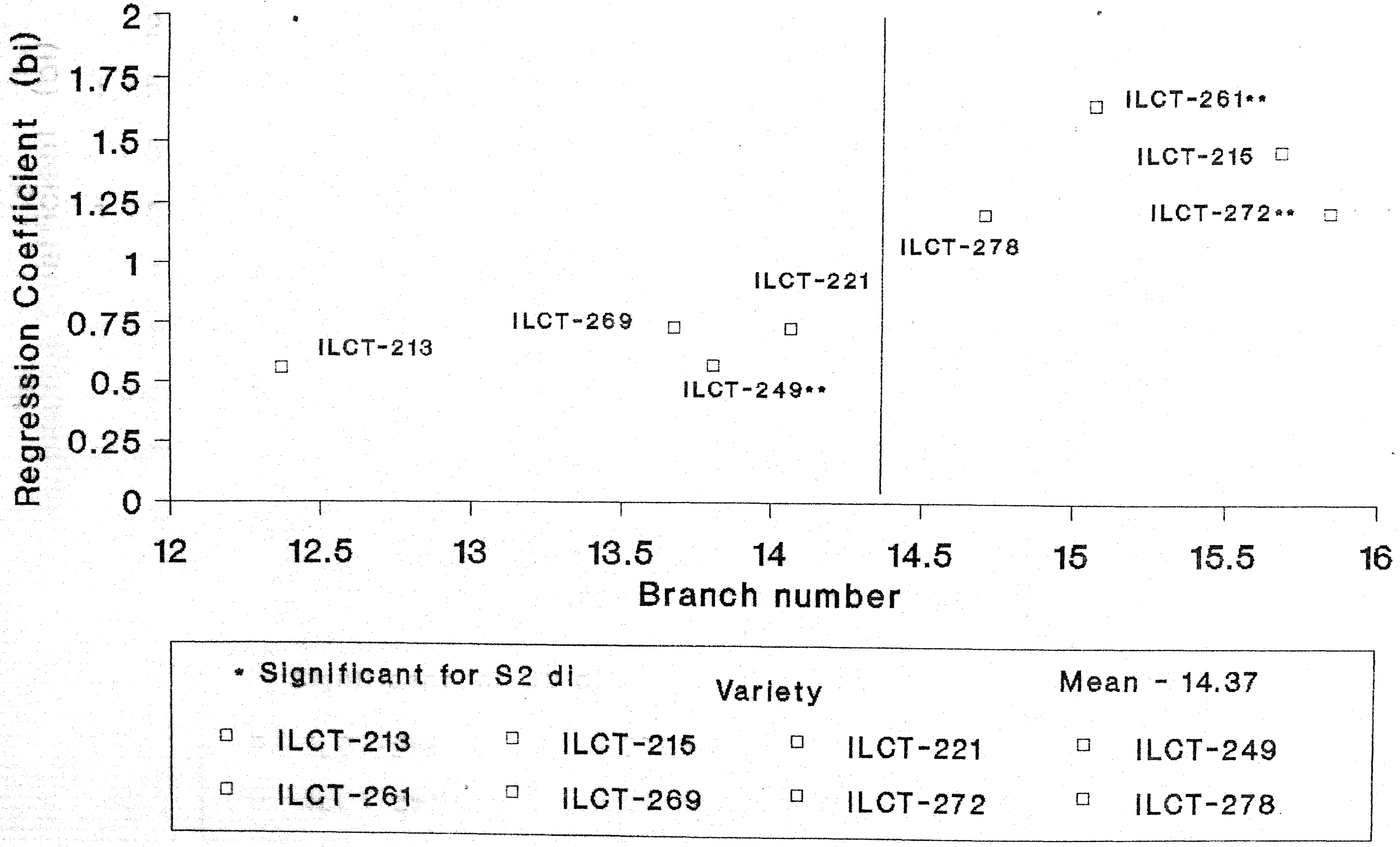


Figure - 11

Stability parameters (bi & S^2di) for GFY/plant (g) in the genotypes of *C. ternatea*

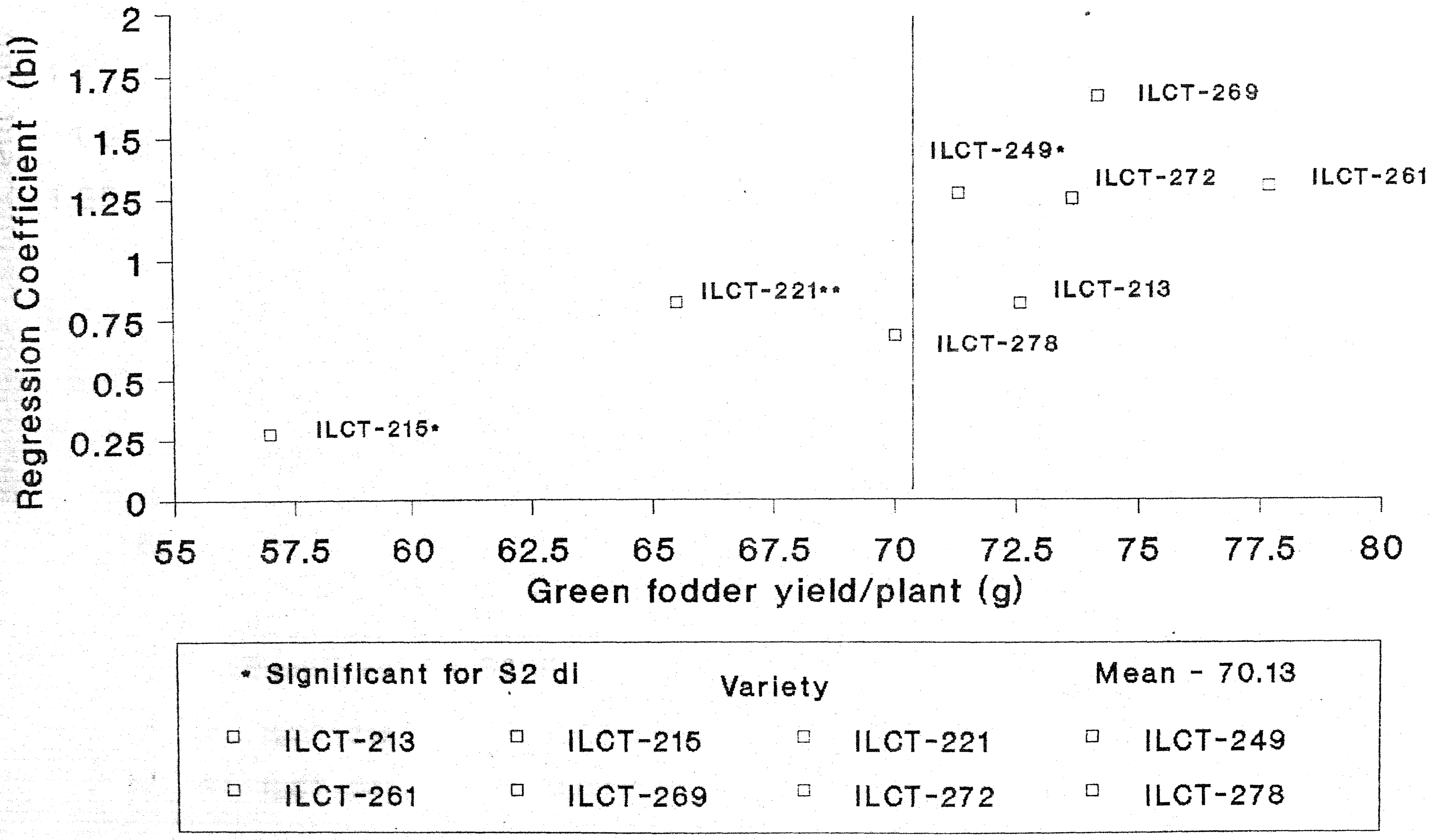


Figure - 12

Stability parameters (bi & S^2di) for DMY/plant (g) in the genotypes of *C. ternatea*

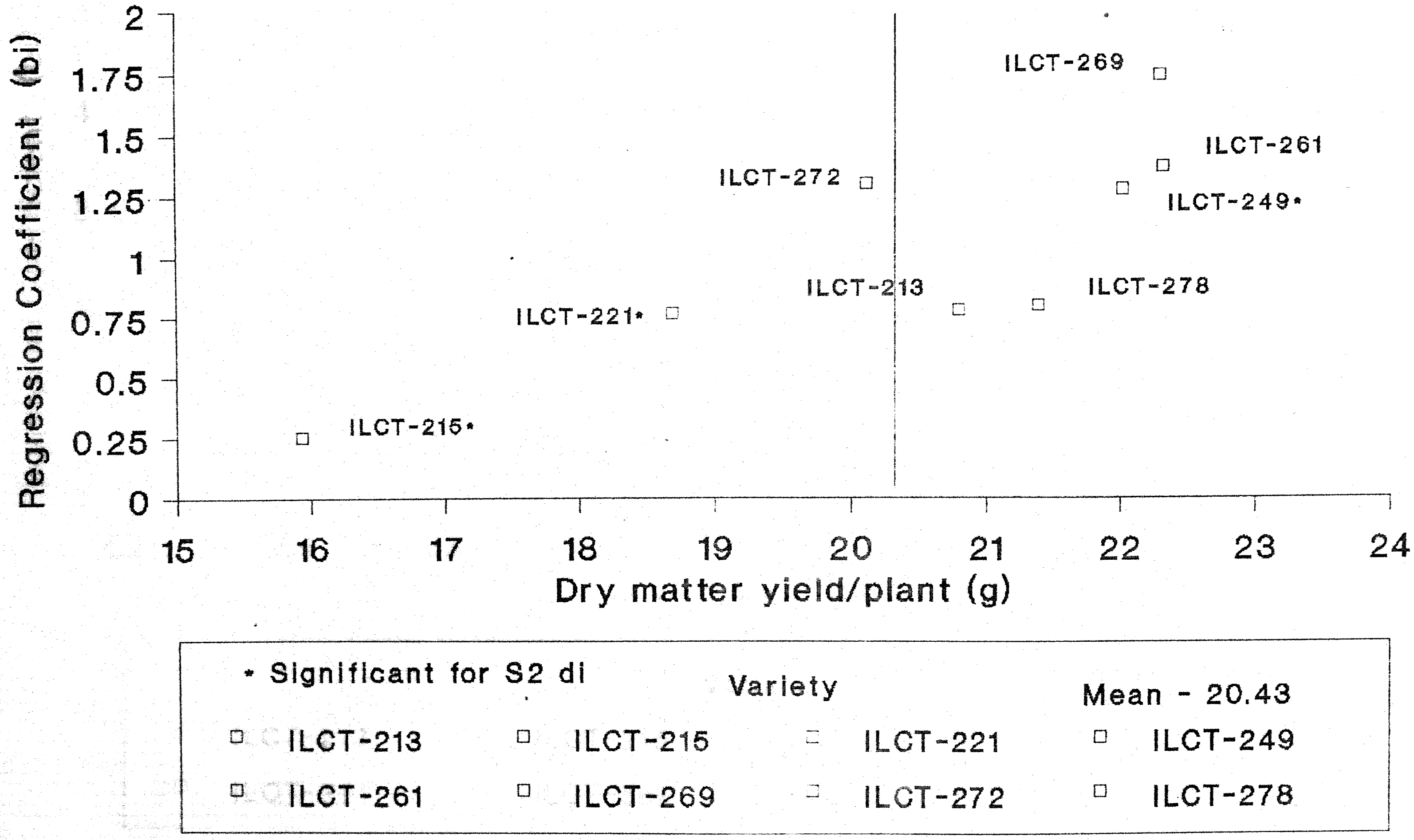


Figure - 13

Stability parameters (bi & S^2di) for leaf-stem ratio in the genotypes of *C. ternatea*

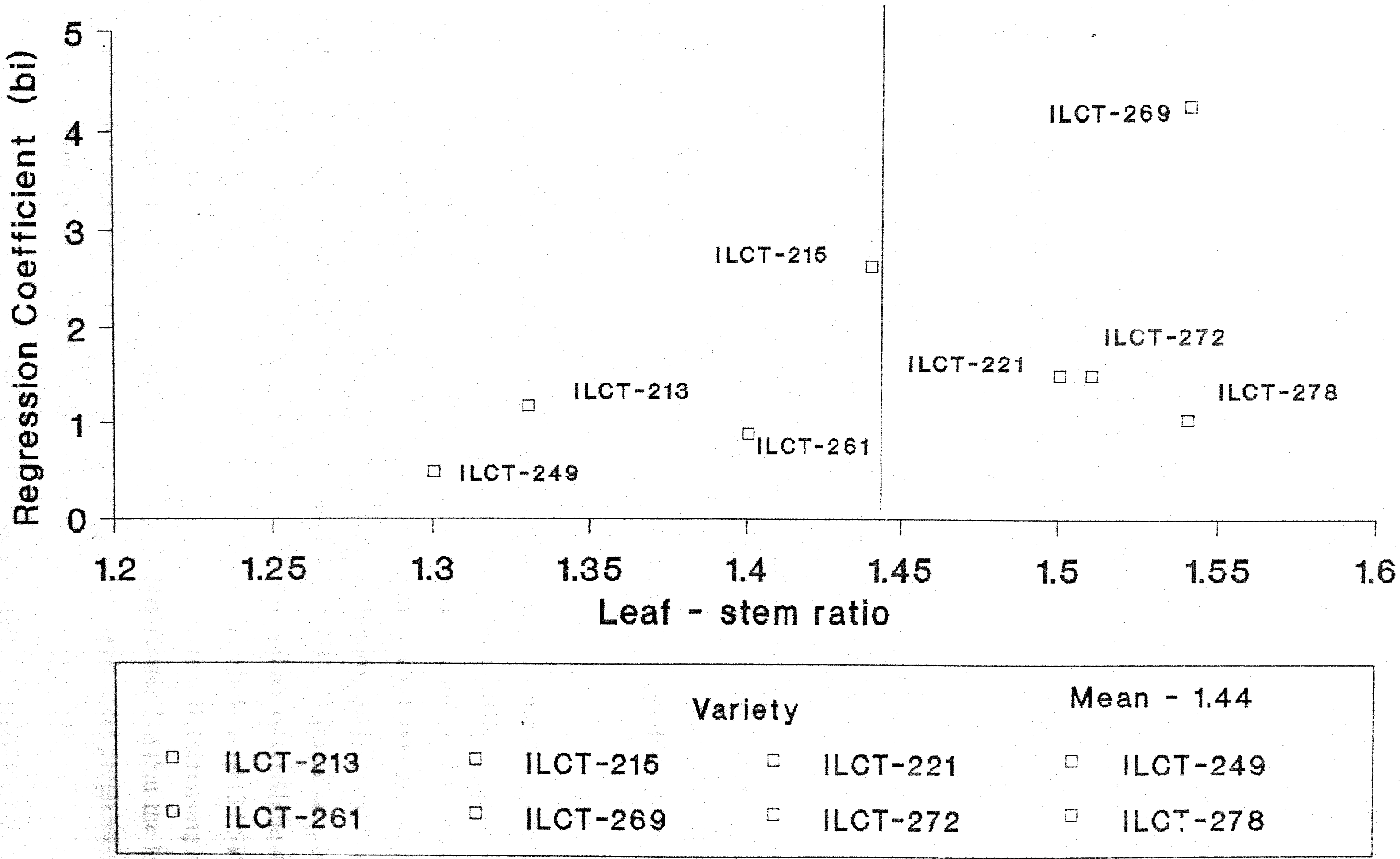


Figure - 14

entries were non-significant (Table 19, Fig 6). The dry matter fodder yield (t/h) of four entries surpassed the over all mean value. Considering regression coefficient (bi and S^2di), only ILCT-278 showed highest stability for DMY (Table 19, Fig 7). The only genotype ILCT-269 which could show desired values for 'bi' and S^2di for crude protein yield (t/h) but its mean value was lower than the overall mean (Table 19, Fig 8). Similar results were observed for seed yield where no genotype appeared to be stable. As regards the plant height (cm) a genotype ILCT-261 showed the best performance as its mean value was above the overall mean and the value of its 'bi' close to unity and non-significant for S^2di (Table 19, Fig 10). For number of branches/ plant, ILCT-278 showed a bit better performance over other entries in the context of each of the stability parameters, however, the information is not much encouraging (Table 19, Fig 11). In case of green fodder yield/plant (g) none of the genotype appeared to be stable as the value of 'bi' was noticed to be much away from unity (Table 19, Fig 12). A similar trend was observed for dry fodder yield/plant (g). In the context of leaf/ stem ratio (Table 19, Fig 14) ILCT-278 was the best among all genotypes as its mean value was 1.54, bi (1.01) say unity and non significant S^2di (0.009).

Relative growth rate (RGR)

The genotypes of butterfly pea showed a wide range of variation in the relative growth rate (RGR) of leaf, stem and leaf + stem (whole plant). The RGR of the whole plant of all the lines studied was maximum during the period of 40 to 50 days of crop growth (RGR-I: 0.098-0.188 $g/g^{-1}/day^{-1}$) but reduced substantially afterwards 50-60 days (RGR-II: 0.11-0.83 $g/g^{-1}/day^{-1}$).

The relative growth rate of the stem component of the plant maintained nearly twice as much growth rate as the leaf during the period 40-60 days (Mean RGR I: leaf-0.0947 $\pm$0.006 and stem - 0.1746$\pm$0.007 $g/g^{-1}/day^{-1}$), but such differences were considerably reduced during the period 50-60 days (RGR II: leaf- 0.0263$\pm$0.002 and stem - 0.03$\pm$0.003 $g/g^{-1}/day^{-1}$). At the early stages (RGR-I) the different genotypes showed greater heterogeneity for the stem (CV 29.56%) than in the leaf (CV 15.21%) and whole plant (CV 15.65%). A similar sequence was maintained at the later stage of growth as well except that the values of coefficient of variation were considerably higher for stem (44.43%), leaf (39.55%) and whole plant (37.50%). The result indicated that there was a progressive reduction in growth rate with increasing size of the plants and its components (Tables 20 and 21). It was evident (Table 21) that the leaf/ stem ratio of the plant along with the relative growth rate of the leaf component got progressively reduced from first to second period of growth (Table 19).

The genotypic heterogeneity as indicated by the values of the coefficient of variation (Tables 20 & 21) for the relative growth rate of the whole plant and its components was

Table 20: Range, mean and coefficient of variation in relative growth rate (RGR) of leaf, stem and plant (leaf + stem) in genotypes of *C. ternatea* (on dry matter basis)

Character	RGR		
	Range	Mean	CV(%)
RGR-I (40-50 days)			
Leaf	0.067-0.138	0.0947 ± 0.006	15.21
Stem	0.136-0.242	0.1764 ± 0.007	29.56
Leaf + stem	0.098-0.188	0.1392 ± 0.003	15.65
RGR-II (50-60 days)			
Leaf	0.010-0.042	0.0263 ± 0.002	39.55
Stem	0.016-0.007	0.03 ± 0.003	44.43
Leaf + stem	0.011-0.043	0.0274 ± 0.004	37.50

Table 21: Mean, dry matter yield (g) of leaf, stem, plant (leaf + stem) and L/S ratio in *C. ternatea* genotypes

Character	40 days		50 days		60 days	
	Mean	CV(%)	Mean	CV(%)	Mean	CV(%)
Leaf	59.42 ± 1.93	19.6	134.87 ± 0.47	14.2	163.52 ± 3.19	16.0
Stem	39.18 ± 1.42	21.0	167.72 ± 0.94	16.7	231.15 ± 4.88	13.0
Leaf + stem (plant)	98.60 ± 3.10	18.8	302.59 ± 1.08	12.5	394.67 ± 7.4	18.6
Leaf- stem ratio	1.83 ± 0.83	23.4	0.93 ± 0.16	19.0	0.78 ± 0.06	10.0

Table 22: Correlation coefficient between the relative growth rates (RGR) and its dry matter yield (DMY) at the beginning and at the end of each growth period and L/S ratio in C.ternatea genotypes.

RGR	RGR leaf	RGR stem	RGR plant	DMY 40 days	L/S ratio	DMY 50 days	L/S ratio	DMY 60 days	L/S ratio
RGR I (40-50 days)									
Leaf		.5632**	.6876**	-.4638**	.0021				
Stem			.9218**	-.7892**	.4312*				
Plant				-.7482**	.2816				
RGR II (50-60 days)									
Leaf		.5368**	.7016**			-.7356**	.0294	-.1923	-.0184
Stem			.8912**			-.6928**	.6281*	.2684	-.2426
Plant						-.7018**	.4231*	-.0986	-.0432

considerably higher (CV 15-44%) than the dry matter yield of the plants at different stages of growth (CV 10-23%).

The association between the RGR values of whole plant, stem and leaf was strongly significant within each of the respective growth periods and the magnitude of the correlations was maximum (0.9210 and 0.8912) between the whole plant and the stem component. Within each growth period the RGR for the whole plant, stem and leaf component showed a negative highly significant correlation with their respective initial dry matter yield ie 40 days for RGR I and 50 days for RGR II (Table 22). The study indicated that the genotypes with low initial dry matter yield tended to grow more aggressively than the ones with higher initial yield (Table 22). On the other hand the leaf/stem ratio was most important as the magnitude of its correlation with stem and the whole plant increased from moderate to high level of significance from first to the second period of growth (Table 22). The study suggest that the selection for aggressive growth types in butterfly pea could be based on high leaf/stem ratio.

Compatibility of *C. ternatea* with grasses

Plant height (cm)

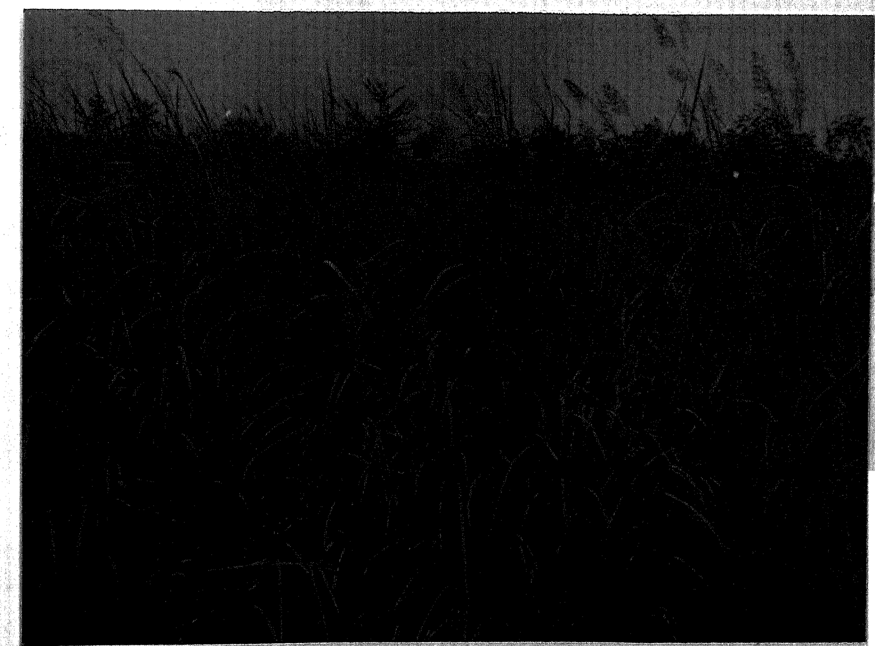
The plant height of *Clitoria* (Butterfly pea) was not affected by different grass combination treatments but was significantly influenced by cutting treatments (Table 23) and also due to different environment in different years. Data of three years (average) indicate that the first cut plant height of *Clitoria* was significantly higher than the second cut. The average plant height in two cuts each year was maximum in first year (1991) and minimum in the second year (1992) of growth (Table 23).

Chrysopogon fulvus (Cf) had significantly taller plants in Cf + Sbl treatment (119.6 cm) as compared to its pure stand or in any other grass + legume combination. In this grass plant height differences due to cuttings were not significant but in the establishment year (1990-91) the plants were significantly taller (145.3 cm) than in the following years *i.e.* 91-92 and 92-93 with 85 and 90 cm height, respectively (Table 23).

The plant height in *H. contortus* (Hc) and *C. ciliaris* (Cc) was not significantly different between their sole and mix crop stands with legume. The plant height was, however, significantly higher in both the grass species in the first cut as compared to the second cut in both the years of observation. Similarly the plant height in these grasses were significantly more in the establishment year than in the following years of growth.

4

Mix stand of legume + grass
(*Clitoria* + *Cenchrus*)



5

Mix stand of legume + grass
(*Clitoria* + *Chrysopogon*)

Table 23: Effect of inter-cropping treatments on plant height (cm) in the component species.

Treatment	Species			
	Clitoria	Chrysopogon	Heteropogon	Cenchrus
Ct	68.0	-	-	-
Cf	-	102.6	-	-
Hc	-	-	76.0	-
Cc	-	-	-	105.5
Ct + Cf	69.7	100.7	-	-
Ct + Hc	67.9	-	72.5	-
Ct + Cc	65.9	-	-	107.5
Ct + Sbl	67.0	-	-	-
Cf + Sbl	-	119.6	-	-
Hc + Sbl	-	-	74.9	-
Cc + Sbl	-	-	-	102.4
Ct + Cf + Sbl	66.8	104.6	-	-
Ct + Hc + Sbl	68.1	-	74.5	-
Ct + Cc + Sbl	63.6	-	-	100.5
SE(m) +	2.15	2.75	2.11	2.52
CD at 5%	NS	7.87	NS	NS
Cutting				
Ist	71.0	109.6	69.0	113.1
IInd	63.1	104.2	80.0	94.8
SE (m) ±	1.07	1.94	1.49	1.75
CD at 5%	3.02	NS	4.25	5.00
Years				
1990	72.6	145.3	82.9	113.6
1991	59.9	85.1	56.3	92.3
1992	68.9	90.2	84.2	105.5
SE (m) ±	1.32	2.38	1.83	2.14
CD at 5%	3.71	6.79	5.20	6.10
CV(%)	13.64	10.94	12.04	10.10

Table 24: Effect of inter-cropping treatments on branch number/tillers per plant in the component species.

Treatment	Species			
	Clitoria	Chrysopogon	Heteropogon	Cenchrus
Ct	11.4	-	-	-
Cf	-	84.2	-	-
Hc	-	-	100.5	-
Cc	-	-	-	65.0
Ct + Cf	11.3	81.6	-	-
Ct + Hc	12.0	-	60.7	-
Ct + Cc	10.5	-	-	78.1
Ct + Sbl	12.8	-	-	-
Cf + Sbl	-	87.8	-	-
Hc + Sbl	-	-	93.2	-
Cc + Sbl	-	-	-	85.2
Ct + Cf + Sbl	9.2	72.8	-	-
Ct + Hc + Sbl	10.8	-	78.8	-
Ct + Cc + Sbl	11.3	-	-	71.9
SE(m) ±	0.57	4.82	4.60	4.30
CD at 5%	1.60	NS	13.09	12.30
Cutting				
Ist	12.5	73.0	85.8	77.8
IInd	9.8	90.0	80.9	72.3
SE (m) ±	0.3	3.4	3.2	3.0
CD at 5%	0.8	9.7	NS	NS
Years				
1990	9.5	25.4	39.1	26.4
1991	13.4	54.8	42.7	53.8
1992	10.6	164.6	168.1	144.9
SE (m) +	0.3	4.2	3.9	8.7
CD at 5%	0.9	11.9	11.3	12.3
CV(%)	22.6	25.1	23.4	24.5

Branch/ tiller number

Branch number of *C.ternatea* (Ct) was significantly influenced by different inter-crop treatments (Table 24). Branch number in *Clitoria* was highest (12.8) in Ct + Sbl combination treatment followed by pure stand of butterfly pea and its combination with *Chrysopogon fulvus* (Cf) and Cc + Sbl. On the other hand minimum branch number was found in Cf + Sbl combination.

Based on an average of three years the first cut branch number of *Clitoria* was significantly higher (12.5) than the second cut (9.8). On the basis of the average of two cuts each year the highest number of branches (13.4) was recorded in the second year followed by the third year (10.6) and first year (9.5) of growth (Table-24).

The grass *Chrysopogon fulvus* (Cf) grown with subabul recorded higher number of tillers (87.8) than in pure stand (84.2). Considerable reduction in grass tiller number (72.8) was observed in case of three species inter-crop combination (*C. ternatea* + *C.fulvus* + subabul) treatment. The number of tillers in this grass increased significantly due to cuttings and environment (years) effect. Highest tillers were observed in third year (164.6) and minimum in the establishment year (25.4).

Tiller number in *H.contortus* was strongly influenced by different inter-crops treatments, cutting and environment in different years (Table 24). Maximum number of tillers (100.5) were recorded in pure stand followed by *H. contortus* + Subabul association (93.2). Maximum reduction in tiller numbers was observed in *Clitoria* + *Heteropogon* followed by *Clitoria* + *Heteropogon* + Subabul combination with 60.7 and 78.8 tillers, respectively. Number of tillers in *Heteropogon* were significantly higher in the first cut as compared to second cut. The size of the tussocks increased with age of the *Heteropogon* plant along with increase in tiller number. Maximum number of tillers were recorded during third year (168.1) followed by second year(42.7) and lowest in the first year (39.1).

The tiller number in *Cenchrus* increased considerably in combination with legumes as compared to its pure stand. It was highest in association with Subabul (85.2) followed by *Clitoria* + *Cenchrus* (78.1) and lowest (65) in pure stand of *Cenchrus*. The first cut recorded significantly higher number of tillers (77.8) as compared to second cut (72.3). Similarly the tiller number in *Cenchrus* increased from 26.4 in the first year to 145 in the third year of growth (Table 24).

6

Mix stand of legume + qrass
(*Clitoria* + *Heteropogon*)

7

Mix stand of three species combination
(*Clitoria* + *Heteropogon* + *Leucaena*)

Crude protein content (%)

Crude protein content in the forage of *Clitoria* differed significantly in the different combination treatment. The most favourable combination was *Clitoria* + Subabul which recorded highest protein content in forage (20.55 %) followed by pure stand of *Clitoria* (18.73 %). Whereas the grass-legume combination *Clitoria* + *Heteropogon* yielded the lowest crude protein content (14.01%) in *Clitoria* herbage. Within the year the protein contents in *Clitoria* herbage was almost similar in the different cuts (16.66 & 16.1%). There was a marginal reduction in the crude protein content in *Clitoria* forage from first year (17.18%) to third year of (15.92 %) growth (Table 25).

The crude protein content of *Chrysopogon fulvus* herbage increased substantially when grown mixed with either *Clitoria* (CP 6.24%) or Subabul (CP 6.37%) than in the sole stands of the grass (CP 5.87%). The CP content in *Chrysopogon* was significantly higher in the Ist cut (6.37%) as compared to the IInd cut (6.04%). There was a decreasing trend in CP contents of the grass with the advancing of age of the plant in subsequent years (Table 25).

Crude protein content in the *Heteropogon contortus* herbage increased significantly in combinations with *Clitoria* (CP 5.4 %) over the pure (CP 4.66%) crop or over any other grass-legume combination treatment (CP 4.9%). There was a marginal decline in CP content of the grass from first year (CP 5.11%) to third year (CP 4.85%) of growth and also from the first (CP 5.15%) to second cutting (CP 4.8%).

Crude protein content in *Cenchrus ciliaris* herbage was not much different in the sole crop (CP 7.37%) and in the different grass-legume combination (CP 6.82 - 7.62%). The cutting treatment had no effect on CP but CP declined from 7.83% in the first year to 6.61% in the third year of growth (Table 25).

Total dry matter yield (biomass) and crude protein yield in grass-legume mixture

Total above ground biomass (inclusive of grass and legume component) in different pure and combination treatments varied significantly. The total biomass in three species combination viz., *Clitoria* + *Cenchrus* + *Subabul* (9.75 t/h) was the highest followed by *Chrysopogon* + *Subabul* (8.86 t/h) and *Clitoria* + *Chrysopogon* + *Subabul* (8.67 t/h). There was a progressive increase in biomass from 4.60 t/h to 7.2 t/h from Ist to IIIrd year of growth (Table 26). In general the grass- legume combination produced 50 to 100% more biomass than the pure crop of the grasses or *Clitoria*. Due to lower plant density of the respective grass and legume component in the mixtures, the biomass of the grass and *Clitoria* component

Table 25: Effect of inter-cropping treatments on crude protein content (%) in the component species.

Treatment	Species			
	Clitoria	Chrysopogon	Heteropogon	Cenchrus
Ct	18.73	-	-	-
Cf	-	5.87	-	-
Hc	-	-	4.66	-
Cc	-	-	-	7.37
Ct + Cf	14.14	6.24	-	-
Ct + Hc	14.01	-	5.40	-
Ct + Cc	15.76	-	-	7.37
Ct + Sbl	20.55	-	-	-
Cf + Sbl	-	6.37	-	-
Hc + Sbl	-	-	4.90	-
Cc + Sbl	-	-	-	6.82
Ct + Cf + Sbl	16.57	6.34	-	-
Ct + Hc + Sbl	16.18	-	4.90	-
Ct + Cc + Sbl	15.20	-	-	7.62
SE(m) ±	0.44	0.08	0.07	0.09
CD at 5%	1.25	0.24	0.20	0.26
Cutting				
Ist	16.66	6.37	5.15	7.37
IInd	16.10	6.04	4.80	7.22
SE (m) ±	0.22	0.06	0.05	0.06
CD at 5%	NS	0.17	0.14	NS
Years				
1990	17.18	6.58	5.11	7.83
1991	16.07	6.22	4.97	7.45
1992	15.92	5.82	4.85	6.61
SE (m) +	0.27	0.07	0.06	0.07
CD at 5%	0.76	0.22	0.18	0.22
CV(%)	11.55	5.97	6.20	5.31

Table 26: Total dry matter and crude protein yield (t/h) of grass and legume components (three years mean) in different combination treatments.

Treatment	Dry mater yield (Biomass) (t/h)	Crude protein yield (CP) (t/h)
C.ternatea Pure	2.59	0.510
C.fulvus Pure	5.16	0.295
H.contortus Pure	2.91	0.133
C.ciliaris Pure	4.43	0.329
C.ternatea + *C.fulvus*	5.61	0.511
C.ternatea + *H.contortus*	3.82	0.363
C.ternatea + *C.ciliaris*	6.22	0.600
C.ternatea + Sbl	5.82	1.131
C.fulvus + Sbl	8.86	0.886
H.contortus + Sbl	6.22	0.645
C.ciliaris + Sbl	8.17	0.821
C.ternatea + *C.fulvus* +Sbl	8.67	0.901
C.ternatea + *H.contortus* +Sbl	6.72	0.862
C.ternatea + *C.ciliaris* +Sbl	9.75	1.114
SE(m) ±	0.30	0.03
CD at 5%	0.84	0.10
CV%	14.52	15.54
Years		
1990	4.60	0.49
1991	6.20	0.74
1992	7.72	0.82
SE (m) ±	0.14	0.01
CD at 5%	0.34	0.04

was generally lower than their biomass in the pure crop. Amongst the grasses *Cenchrus* was the only exception with slightly lower or slightly increased biomass in mixed stand than its pure stand (Table 27). On the other hand the *Clitoria* biomass in the mixed stand of Subabul (3.02 t/h) was considerably higher than that of *Clitoria* pure (2.59 t/h). *Clitoria* being a creeper ostensibly took advantage of trailing over the Subabul plant and intercepting more light energy than in the pure crop of *Clitoria*. The biomass of *Heteropogon* when inter-cropped separately with *Clitoria* and *Subabul* increased by a margin of 31.2% and 113.7%, respectively, over the pure crop of *Heteropogon*. When both the legumes were companion crop of *Heteropogon* the biomass increase over pure crop of *Heteropogon* was 131% (Table 29). Similar results were also obtained when *Chrysopogon/Cenchrus* were intercropped with *Clitoria and Subabul* separately and also when both the legume species together were intercropped with the individual grasses (Table 29).

The crude protein yield varied significantly in the different treatments (Table 28). The results indicated maximum CP yield from *Subabul+ Clitoria* (1.137 t/h) followed by *Subabul + Clitoria + Cenchrus* (1.114 t/h). The remaining combinations of Subabul with different grasses and *Clitoria* had a CP yield range of 0.645 - 0.901 t/h. The percentage of CP (Table 28) in the forage was maximum for *Clitoria* (19.7%) followed by *Cenchrus* (7.4%), *Chrysopogon* (5.7%) and lowest for *Heteropogon* (4.6%). The highest CP yield was recorded in the combination of *Clitoria* with *Cenchrus* (0.60 t/h) where a gain of 17.6% CPY over the pure stand of *Clitoria* was obtained (Table 30) which was followed by *Clitoria + Chrysopogon* (0.511 t/h) and *Clitoria + Heteropogon* (0.363 t/h). Amongst the grasses, the most productive species in terms of CP yield in the pure and mixed stand was *Cenchrus* followed by *Chrysopogon* and *Heteropogon* (Table 26). The grass *Heteropogon* despite being the lowest producer for dry matter and CP yield in pure stand, was most benefited by its combination with *Clitoria*. Unlike combination treatment, the CP yield in the pure crop was 0.51 t/h for *Clitoria* and 0.133 - 0.329 t/h in the different grasses. The CP yield of the grass component ranged between 0.107 to 0.298 t/h when mixed with the legume *Clitoria*. But when the same grasses and the *Clitoria* were mixed with Subabul the CP yield of the grass component was 0.128 - 0.335 t/h and for *Clitoria* component 0.607 t/h. In the three species combination the yield of all the grass species component except *Cenchrus* decreased considerably than the pure crop stand of the respective grasses. It may be noted that increased protein yield of *Cenchrus* component in the grass-legume mixture occurred despite nearly half the plant density as compared to its pure stand. The protein yield was significantly influenced by the environmental factors in the different years. The CP yield increased from 0.49 t/h to 0.82 t/h from Ist to IIIrd year of growth. Amongst all the treatments the most beneficial combination in terms of biomass and CP yield was *Clitoria + Cenchrus + Subabul* followed by *Clitoria + Chrysopogon + Subabul* (Table 26).

The legumes in general helped in increasing the protein content of the herbage of

Table 27: Dry matter yield (t/h) and percentage contribution of various grass and legume components under different intercropping treatments.

Treatment	Ct	Cf	Hc	Cc	Sbl	Total
Ct Pure	2.59	-	-	-	-	2.59
Cf Pure	-	5.16	-	-	-	5.16
Hc Pure	-	-	2.91	-	-	2.91
Cc Pure	-	-	-	4.43	-	4.43
Ct + Cf	1.90 (33.8)	3.71 (66.2)	-	-	-	5.61
Ct + Hc	1.81 (47.0)	-	2.01 (53.0)	-	-	3.82
Ct + Cc	2.06 (33.0)	-	-	4.16 (67.0)	-	6.22
Ct + Sbl	3.02 (52.0)	-	-	-	2.80 (48.0)	5.82
Cf + Sbl	-	5.08 (57.0)	-	-	3.78 (43.0)	8.86
Hc + Sbl	-	-	2.65 (43.0)	-	3.57 (57.0)	6.22
Cc + Sbl	-	-	-	4.94 (60.0)	3.23 (40.0)	8.17
Ct + Cf + Sbl	2.04 (23.0)	3.40 (40.0)	-	-	3.23 (37.0)	8.67
Ct + Hc + Sbl	1.80 (27.0)	-	1.87 (28.0)	-	3.05 (45.0)	6.72
Ct + Cc + Sbl	1.93 (20.0)	-	-	4.53 (46.0)	3.29 (34.0)	9.75

Figures in ( ) represent the percentage dry matter contribution of component species.

Table 28: Total crude protein yield (t/h), CP content (%) and the percentage CP contribution from component species in different inter-cropping treatments.

Treatment	Ct	Cf	Hc	Cc	Sbl	Total
Ct Pure	0.510 (19.7)	-	-	-	-	0.510
Cf Pure	-	0.295 (5.7)	-	-	-	0.295
Hc Pure	-	-	0.133 (4.6)	-	-	0.133
Cc Pure	-	-	-	0.329 (7.4)	-	0.329
Ct + Cf	0.284 (14.9) 49.0	0.227 (6.1) 51.0	-	-	-	0.511
Ct + Hc	0.256 (14.1) 70.0	-	0.107 (5.3) 30.0	-	-	0.363
Ct + Cc	0.302 (16.6) 50.0	-	-	0.298 (7.6) 50.0	-	0.600
Ct + Sbl	0.607 (20.1) 53.0	-	-	-	0.530 (18.9) 47.0	1.137
Cf + Sbl		0.312 (6.1) 35.0	-	-	0.574 (15.2) 65.0	0.886
Hc + Sbl	-	-	0.128 (4.8) 20.0	-	0.517 (14.5) 80.0	0.645
Cc + Sbl	-	-	-	0.335 (6.8) 41.0	0.486 (15.0) 59.0	0.821
Ct + Cf + Sbl	0.350 (17.1) 39.0	0.201 (5.9) 22.0	-	-	0.350 (10.8) 39.0	0.901
Ct + Hc + Sbl	0.296 (16.4) 34.0	-	0.096 (5.1) 23.0	-	0.470 (15.4) 43.0	0.862
Ct + Cc + Sbl	0.320 (16.8) 29.0	-	-	0.341 (7.5) 30.0	0.453 (13.7) 41.0	1.114

Figure in ( ) represent the CP per cent.

Table 29: Comparative performance for dry matter yield (t/h) of grass-legume components in different inter - cropping treatment combinations.

Treatments	Clitoria	Chrysopogon	Heteropogon	Cenchrus
Pure	2.59	5.16	2.91	4.43
Ct + grass	-	5.61	3.82	6.22
Sbl + grass	-	8.86	6.22	8.17
Ct + grass + Sbl	-	8.67	6.72	9.75
%age increase over grass pure				
Ct + grass	-	8.7	31.2	40.4
Sbl + grass	-	71.7	113.7	84.4
Ct + grass + Sbl	-	68.0	130.9	120.0
%age increase over Clitoria pure				
Ct + grass	-	116.0	47.0	140.0
Sbl + grass	-	242.0	140.0	111.0
Ct + grass + Sbl	-	234.0	159.0	276.0
%age increase over (Clitoria + grass)				
Sbl + grass	-	57.9	62.8	31.3
Ct + grass + Sbl	-	54.5	75.9	56.7

Table 30: Comparative performance for crude protein yield (t/h) of grass-legume components in different inter-cropping treatment combinations.

Treats.	Clitoria	Chrysopogon	Heteropogon	Cenchrus
Pure	0.511	0.295	0.133	0.329
Ct + grass	-	0.511	0.363	0.600
Sbl + grass	-	0.886	0.645	0.821
Ct + grass + Sbl	-	0.901	0.862	1.114
%age increase over grass pure				
Ct + grass	-	73.2	174.0	82.4
Sbl + grass	-	200.3	384.0	149.5
Ct + grass + Sbl	-	205.4	548.1	237.7
%age increase over Clitoria pure				
Ct + grass	-	0.20	(-)29.0	17.6
Sbl + grass	-	73.7	26.4	61.0
Ct + grass + Sbl	-	76.0	69.0	118.4
%age increase over Clitoria + Grass				
Sbl + grass	-	73.4	77.6	36.8
Ct + grass + Sbl	-	76.3	137.4	85.6

the companion grass *Chrysopogon* from 5.72% to 6.14% and of *Heteropogon* from 4.57% to 5.32% and therefore improved the overall forage quality of the herbage. In case of *Cenchrus* the CP% of the herbage in pure crop (7.43%) was substantially higher as compared to any other grass either in pure or in the mixed stand (4.57-6.14%). But on the other hand *Cenchrus* was least benefited in CP of its forage through legumes than other grasses.

The percentage increase of biomass of the *Chrysopogon*-legume combination over the pure stand of the grass was 8.7% in case of mixture with Clitoria, 17.7% in mixture with Subabul and 68% when both the legumes were mixed with grass (Table 29). Subabul combination with *Chrysopogon or subabul* combination with *Chrysopogon* + *Clitoria* registered an increase in biomass production of 57.9% and 54.5%, respectively, over *Clitoria* + *Chrysopogon* combination. The percentage increase of biomass of the *Heteropogon* grass was 31.2% when intercropped with *Clitoria*, 113.7% with Subabul and 131% with *Subabul* + *Clitoria*. *Heteropogon* combination with Subabul or with *Subabul* + *Clitoria* registered an increase of 62.8% and 76%, respectively, as compared to *Heteropogon* + *Clitoria* combination. The percentage increase of biomass of the *Cenchrus* was 40.4% when intercropped with *Clitoria*, 84.4% with Subabul and 120% with *Subabul* + *Clitoria* (Table 29). *Cenchrus* combination with Subabul or with *Subabul* + *Clitoria* was 31.3% and 56.7%, respectively, as compared to *Cenchrus* + *Clitoria*.

The study indicated that the most beneficial combination in term of crude protein yield was *Clitoria* + *Subabul* (1.137 t/h) followed by three species combination *Clitoria* + *Cenchrus* + *Subabul* (1.114 t/h). The later combination also had the higher dry matter yield (9.75 t/h) among all the treatments.

The Subabul combination with grasses resulted in an increase of 26-73% CPY and the *Clitoria* + grass + Subabul gave 69-118% more CPY over the pure crop of *Clitoria*. As compared to the pure crop of grasses the CP yield of *Clitoria* + grass increased by a margin of 73- 174%, Subabul + grass 150-300% and *Clitoria* + grass +Subabul by a margin of 215-548% (Table 30).

Interaction effects of cutting and year on dry matter yield of *C. ternatea*

Cutting effect on the treatments was highly significant for biomass of *Clitoria* (Table 31). The first cut yield of *Clitoria* in all the treatments was significantly higher than the second cut. Within the first cut the *Clitoria* biomass in pure stand and in combination with Subabul gave significantly higher yield than in any other treatments. A similar pattern was also observed for the mean biomass of the two cuts. But such differences between the treatments were not evident within the second cut of *Clitoria* (Table 31).

Table 31: Effect of cutting *X* treatments on dry matter yield (t/h) of *C.ternatea* in different intercropping treatment combinations.

Treatments	C-1	C-2	Mean
Ct Pure	1.91	0.73	1.32
Ct + Cf	1.16	0.75	0.95
Ct + Hc	1.10	0.69	0.90
Ct + Cc	1.21	0.74	0.97
Ct + Sbl	1.95	1.06	1.51
Ct + Cf + Sbl	1.26	0.79	1.02
Ct + Hc + Sbl	1.09	0.71	0.90
Ct + Cc + Sbl	1.92	0.74	0.96
Mean	1.35	0.77	1.06
SE (m) ±	0.09		
CD at 5%	0.27		
`F' Value	4.73		

C-1 = First cut C-2 = Second cut

Table 32 : Effect of year *X* treatments on dry matter yield (t/h) of *C.ternatea* in different intercropping treatment combinations.

Treatments	Y-1	Y-2	Y-3	Mean
Ct Pure	2.20	1.15	0.60	1.32
Ct + Cf	1.80	0.73	0.32	0.95
Ct + Hc	1.40	0.82	0.47	0.90
Ct + Cc	1.37	1.01	0.54	0.97
Ct + Sbl	2.60	1.20	0.73	1.51
Ct + Cf + Sbl	1.72	0.86	0.48	1.02
Ct + Hc + Sbl	1.51	0.86	0.33	0.90
Ct + Cc + Sbl	1.48	0.97	0.43	0.96
Mean	1.76	0.95	0.49	1.06
SE (m) $\pm$	0.11			
CD at 5%	0.32			
`F' Value	3.12			

Y-1 = First year Y-2 = Second year Y-3 = Third year

Table 33 : Effect of cutting *X* years on dry matter yield (t/h) of *C. ternatea* in different intercropping treatment combinations.

Cuttings	Y-1	Y-2	Y-3	Mean
C-1	2.38	1.13	0.56	1.36
C-2	1.13	0.77	0.42	0.77
Mean	1.76	0.95	0.49	1.06
SE (m) ±	0.05			
CD at 5%	0.16			
`F' Value	50.80			

Y-1 = First year Y-2 = Second year Y-3 = Third year
C-1 = First cut C-2 = Second cut

Table 34 : Effect of treatments X cutting X years on dry matter yield (t/h) of *C.ternatea* in different intercropping treatment combinations.

Treatments	Y-1		Y-2		Y-3	
	C-1	C-2	C-1	C-2	C-1	C-2
Ct Pure	3.23	1.16	1.60	0.71	0.90	0.30
Ct + Cf	2.35	1.23	0.77	0.70	0.35	0.30
Ct + Hc	2.06	0.73	0.87	0.78	0.40	0.57
Ct + Cc	1.64	1.10	1.17	0.86	0.81	0.26
Ct + Sbl	3.64	1.53	1.60	0.77	0.58	0.89
Ct + Cf + Sbl	2.17	1.30	0.98	0.74	0.62	0.34
Ct + Hc + Sbl	1.93	1.08	0.96	0.76	0.38	0.28
Ct + Cc + Sbl	2.01	0.96	1.13	0.81	0.43	0.42
Mean	2.37	1.13	1.13	0.76	0.55	0.42
SE (m) ±	0.16					
CD at 5%	0.46					
`F'Value	2.63					

Y-1 = First year Y-2 = Second year Y-3 = Third year
C-1 = First cut C-2 = Second cut

The growing environment in the different years had significant effect on the *Clitoria* biomass of the different treatments (Table 32). The first year biomass of *Clitoria* was significantly higher than the second and subsequent year's biomass. Within the year *Clitoria* biomass in pure stand and in combination with Subabul was significantly higher than all other treatments during the first year and most of the treatments during the second year of growth. The mean biomass of all the three years followed a similar pattern as in the first year (Table 32).

Cutting *X* year interaction was highly significant for *Clitoria* biomass (Table 33). The first cut biomass of *Clitoria* in all the years was significantly higher than the second cut yield. The respective biomass of the first and second cut showed a progressively highly significant reduction from first to third year of growth (Table 33). The effect of cutting *X* year *X* treatment were moderately significant for the *Clitoria* biomass. The first cut biomass of the first year of growth in all the treatments was significantly higher than that of the first and second cut biomass obtained in the second and subsequent year's of plant regrowth (Table 34).

Interaction effects on crude protein content (%) of *C. ternatea*

The interaction due to cutting X treatment on crude protein content (%) of butterfly pea was moderately significant (Table 34). Most of the mix crop treatments maintained a similar level of Clitoria protein content in both the cuttings. The *Clitoria* CP % improved significantly from 18.72 % in the pure stand to 20.67 % in combination with Subabul but was significantly decreased (CP 13.86 % - 15.52 %) when intercropped with the different grasses. The crude protein content of *Clitoria* when mix cropped with Subabul + grasses (CP 15.95% - 16.74%) was significantly higher than all the *Clitoria* + grass combination treatments (Table 35).

The interaction due to year *X* treatments was significant for CP content (%) of *Clitoria* (Table 36). In most of the mix crop treatments there was a progressive reduction, often to a significant level, in the protein content of *Clitoria* from first year to the third year of growth. Only in case of *Clitoria* + *Cenchrus* + *Subabul* treatment there was a significant improvement in the CP content of *Clitoria* from first year (16%) to second year (17.71%). The CP content of *Clitoria* in the first cut was not significantly different between the first (17.33%) and second year (17.11%) of growth (Table 37). But there was a significant reduction in the CP content of *Clitoria* from second to third year of growth for both the cuttings and between first to second year for the second cutting. The interaction of treatment *X* cutting *X* year was highly significant for *Clitoria* crude protein content (Table 38).

Table 35 : Effect of treatment *X* cutting on CP content (%) of *C. ternatea* in different intercropping treatment combinations.

Treatments	C-1	C-2	Mean
Ct Pure	18.74	18.70	18.72
Ct + Cf	14.63	13.83	14.23
Ct + Hc	14.03	13.69	13.86
Ct + Cc	15.71	15.33	15.52
Ct + Sbl	20.49	20.90	20.67
Ct + Cf + Sbl	16.89	16.59	16.74
Ct + Hc + Sbl	16.54	15.96	16.25
Ct + Cc + Sbl	15.85	16.05	15.95
SE (m) ±	0.20		
CD at 5%	0.56		
`F' Value	2.01		

C-1 = First cut C-2 = Second cut

Table 36: Effect of treatment X years on CP content (%) of *C. ternatea* in different intercropping treatments combinations.

Treatments	Y-1	Y-2	Y-3	Mean
Ct Pure	19.00	19.29	17.98	18.76
Ct + Cf	19.52	14.11	13.06	14.23
Ct + Hc	14.63	13.81	13.14	13.86
Ct + Cc	17.21	15.38	13.96	15.52
Ct + Sbl	20.84	20.81	20.43	20.69
Ct + Cf + Sbl	18.30	16.15	15.77	16.71
Ct + Hc + Sbl	16.70	16.78	15.26	16.25
Ct + Cc + Sbl	16.00	17.71	14.12	15.94
SE (m) ±	0.214			
CD at 5 %	0.69			
'F' Value	9.40			

Y-1 = First year Y-2 = Second year Y-3 = Third year

Table 37: Effect of cutting X years on the CP content (%) of *Clitoria ternatea* in different intercropping treatment combinations.

Cuttings	Y-1	Y-2	Y-3	Mean
C-1	17.33	17.11	15.38	16.60
C-2	17.22	16.40	15.55	16.39
SE (m) ±	0.12			
CD at 5%	0.34			
`F'	6.70			

Y-1 = First year Y-2 = Second year Y-3 = Third year
C-1 = First cut C-2 = Second cut

Table 38: Effect of treatment X cutting X years on crude protein content (%) of *C. ternatea* in different intercropping treatment combinations.

Treatments	Y-1		Y-2		Y-3	
	C-1	C-2	C-1	C-2	C-1	C-2
Ct Pure	18.34	19.67	20.15	18.42	17.73	18.37
Ct + Cf	16.14	14.90	14.42	13.80	13.33	12.79
Ct + Hc	14.48	13.58	13.86	13.76	13.75	13.04
Ct + Cc	17.75	14.49	15.49	15.27	13.88	14.04
Ct + Sbl	21.34	20.35	20.43	20.19	19.70	21.16
Ct + Cf + Sbl	19.04	17.55	15.75	16.53	15.87	15.67
Ct + Hc + Sbl	16.16	17.25	18.32	15.24	15.16	15.39
Ct + Cc + Sbl	14.19	17.09	18.46	16.72	14.16	14.08
SE (m) ±	0.35					
CD at 5%	0.98					
'F' Value	7.44					

Y-1 = First year Y-2 = Second year Y-3 = Third year
C-1 = First cut C-2 = Second cut

5

DISCUSSION

The legume *Clitoria ternatea* L. commonly known as Butterfly pea in English or Aparajita in Hindi and Sanskrit is indigenous to India where it is adapted throughout the tropical regions having a rain fall range of 500-1500 mm. It is a perennial pasture legume highly productive under warm humid conditions *i.e.* the rainy season. This legume has not yet been exploited to an appreciable extent for upgrading the productivity of the native pastures in this country . One of the main reason is a general lack of relevant information on the various aspects such as the extent of genetic diversity in the indigenous genotypes, factors related to its establishment in the pasture and its production behaviour under mix crop situation against the different native grasses. The basic material of the present study comprises the germplasm collection from major areas of distribution of this indigenous species such as Rajasthan, Uttar-Pradesh, Delhi, Madhya-Pradesh , Gujrat, Maharashtra, Tamil Nadu, Bihar diversity all the *Clitoria ternatea* genotypes were grown in replicated trial and the data on various plant attributes and productivity were recorded at the peak period of the plant growth, *i.e.* at 50% flowering stage.

Genetic diversity

(I) Seed coat colour patterns

The seed coat colour is an important differentiating character in the grouping/clustering of the different genotypes of *Clitoria*. A preliminary grouping of the *Clitoria* genotypes was made on the basis of seed coat colour . The basic seed coat colours are buff to various shades of light brown to black (Bogdan, 1977 ; Singh and Singh, 1988). In the present study it was observed that the various types of seed coat patterns developed through a uniform sprinkling of fine dots or speckles of various colour and sizes over the basic seed coat colour (Plate 1). Several seed types were uniformly brown or black coloured . The grey speckled seed coat colour types were most frequent followed by shining black and dark brown types with or without dottings /speckling . The seed coat colour of legumes was studied by many geneticists. It is known that two distinct types of pigments namely Anthocyanin and Melanin are responsible for the development of seed coat colour patterns in Papilionaceous species. Studies have shown the presence of six genetically controlled colour factors and through the interaction of these factors many seed coat colour patterns emerge out (Spillman and Sando, 1930). The black seed colour is monogenetically dominant over the brown seeds (Smith, 1956). In other studies it was noted that the black colour is monogenetically dominant over salmon, salmon over brown, brown over cream or pinkish cream colour (Sen and Bhowal, 1961). In cowpea

as many as 12 distinct seed coat colour groups were identified (Mehra *et al.* 1974).

(II) Flower attributes

Clitoria is a profusely flowering plant valued for its ornamental display of attractive range of flower colours. The flower is characterised by a much larger size (3-4 cm) of the pair of wings than the standard and the keel. Generally the components of the corolla have fused wings, standard and the keel. But the accession from Tamil Nadu present a composite flower structure with several free wings and standard. It is the wings which conspicuously show various colours ranging from deep blue to whitish blue or white with a different tinge of blue/ and or pink colour. The deep blue is the dominant colour frequently encountered in the genotypes followed by white or various shades of pink against white or light blue (Plate 2). Some of the species of *Clitoria* such as *C.marina, C.falcata, C.fairchildiana* are reported to have fragrant mauve coloured flowers of ornamental importance (Allen and Allen, 1981 ; Arora and Singh, 1987).

Under climatic conditions at Jhansi (Fig. 2, 3 & 4) the flowering response of *Clitoria ternatea* genotypes was day neutral. In this species flowering was initiated during the middle of August to early September. Both vegetative and reproductive growth continue simultaneously until late September, afterwards the growth activity progressively ceased with the increase in self defoliation and bearing of the pods by the end of November. The plants remained dormant during the winter season but regular vegetative regrowth ensued with the advent of warm humid season. In the establishment year different genotypes flowered between 39 to 60 days after sowing but plants in the following years flowered between 37 to 54 days after first monsoon rain (Table 7). Based on an average of three years majority of the genotypes (64%) can be grouped into medium (flowered in 43-46 days) followed by late (19.6%) and early (16.3%) flowering types (Table 6). Although significant genotypic differences for days to flowering within each year were evident ('F' Value 4.8- 45.96), but due to day neutral behaviour of the species, the discernible genotypic variations in flowering were rather low (CV 1.40-4.0 %).

(III) Morphological traits

A wide range of variation was observed in all the ten morphological traits studied. The analysis of variance showed significant differences among the genotypes for all the characters in each individual year of the study (Table 7). Based on the mean values of the three years data the genetic diversity amongst the genotypes was observed in green fodder yield (CV 35 %) followed by leaf number/plant (CV 31 %) and comparatively narrow for branch number/plant (CV 14 %) and days to flower (CV 15 %). The genotypes showed medium genetic diversity (CV 20 %) for the characters of elongation such as plant height and length of the branch.

Clitoria being a creeper shows indeterminate growth and the growth occurs from the growing tips of the main stem and the auxiliary branches (Hall, 1992). Amongst the genotypes a wide range in the size of the plants was observed. Based on three years data the percentage proportion of the genotypes with longest stem and the branch was 18.5 % and 6.6%, medium length of the plant and branch in 49 % and 51 %, and short plant and branch length in 32 % and 41 %, respectively, (Table 6). The respective average length of the plant and the branch during the first and the second year of growth was more or less similar but was comparatively low in the third year (Table 7).

Clitoria is a profusely branched plant and wide variations exist in the magnitude of branching in the different genotypes. The percentage proportion of the genotypes with high number of primary and secondary branches was 14% and 6.6 %, medium number in 51 % and 55 % and low number in 35 % and 38 %, respectively, (Table 6). There was a tendency of an increase in primary and secondary branch number from first to second year of the growth but their number decreased considerably for primary branch and to some extent in the secondary branch in the third year of the plant growth (Table 7).

The leaf number / plant with CV 31 % was one of the most variable character in *Clitoria* genotypes (Table 5). The percentage proportion of genotypes with high number of leaves / plant (152-183) was 21 %, medium (121-152) in 32 % and low (90-121) in 48 % (Table 6).

The character, leaf/stem ratio showed moderate variation CV 27 % amongst the genotypes (Table 5). The percentage proportion of the genotypes with high leaf-stem ratio (1.05-1.24) was 23 %, medium (0.84-1.04) in 53 % and low (0.64-0.83) in 24 % (Table 6),respectively. The *Clitoria* plants were most leafy in the second year (171 leaves/plant) of the growth followed by that in the establishment year (111 leaves / plant) and third year (104 leaves / plant) of growth (Table 7).

The green fodder yield (GFY) was the most variable (CV 35 %) and dry matter yield (DMY) moderately variable (CV 25 %) character in the genotypes (Table 5). The GFY and DMY ranged between 39-97 g /plant and 11-27 g/plant (Table 6). The percentage proportion of the genotypes with high GFY and DMY was 10 % and 18 %, medium 36 % and 39 % and low 54 and 43 %, respectively,
(Table 6). The maximum GFY and DMY per plant was obtained in the second year of the growth followed by third year and the establishment year (Table 7).

(IV) Crude protein content (%)

The crude protein content (CP %) in *Clitoria* herbage was relatively a less variable

character in the genotypes and ranged from 20 to 27 % (Table 5). The percentage proportion of the genotypes with high CP % (24.7-27 %) was 31.6 %, medium (22.4-24.7 %), 46.7 % and low (20.1-22.4) 21.7 % (Table 6). There was a progressive increase in the protein content from 21 % in the establishment year to 25.8 % in the third year of growth.

The results of the study indicated that the *Clitoria* plants in the establishment year have the highest leaf/stem ratio and the longest branch as compared to its regrowth performance in the following years . The next year of regrowth was characterised by an overall increase in size of the plants including branch number, leaf number and maximum realization of yield potential, both GFY and DMY as compared to any other year of growth. The vigour of the *Clitoria* plants in the second year appear to be linked with the maximum foliage number entailing largest surface area available for photosynthetic activity. The unique feature of the *Clitoria* plant is that its protein content continues to increase from the first year to the third year of growth.

Classification, cataloguing and documentation of *Clitoria* germplasm

(A) Index score method of classification

The classification of the *Clitoria* genotypes in the present study is based on the index score method developed by Anderson (1957). All the individual characters were assigned index score values such as; 0 - for low expression, 1- for medium and 2- for high expression. By summing up the index score values for all the 10 characters the total index values (TIV) for each of the genotypes were worked out separately. The TIV being a multi-character expression data connote that the genotypes with low TIV were the less vigorous growth types than those with higher TIV values. The genotypes were distributed into TIV ranging from 1 to 15 (Figure 5, Table 10). The percentage proportion of the genotypes falling in the low (TIV 1-4), medium (TIV 5-8), high (TIV 9-12) and very high grades (TIV > 13) of plant growth types were 16%, 24 %, 49% and 11 %, respectively (Table 10). The materials from the different regions were randomly represented in all the TIV grades of plant growth types (Table 8 & 9).

The results indicate existence of considerable genetic diversity within the major geographical areas of distribution of *Clitoria ternatea*. Presence of divergent growth forms in the materials from the same region may as well indicate that the different plant types may have differential adaptation to the varying range of soil climatic conditions prevailing within the broad expanse of the different regions of *Clitoria* adaptation. The legume is known to perform differently under different growing conditions (Hall, 1985). It is plausible that some genotypes of *Clitoria* may have shown better adaptation and production on the red sandy soils at Jhansi than other types. As there is no evidence to suggest that *Clitoria ternatea* was never in long

term cultivation in this country it is likely that natural causes rather than conscious human selections may have played a dominant role in the evolution of the present day genetic diversity in this indigenous material. In cases where geographically distant locations do not differ sufficiently in soil climatic conditions and management; merely the barrier of distance may not be potent enough to accumulate discernible genetic variability.

During the present days there have been frequent exchange of genetic material between states and countries. Obviously the importance of geographical diversity is getting very much eroded due to frequent exchanges of materials from one region to other. Prevalence of even occasional out crossing in an other wise self pollinated species such as *Clitoria* would result in perpetual maintenance of certain degree of genetic diversity within the same geographical area or the place where the species is naturally present in abundance. Genetic diversity prevalent at its centre of origin permits the retention of cryptic genetic variability under cultivation as observed in oats (Mehra, 1978). It may be pointed out that the selection for adaptive fitness over long period of time under the diverse environmental condition may cause greater genetic diversity amongst the materials from the different regions. Evolution of extremely divergent growth forms along with intermediate types within the different regions would suggest introgression of genes between the extreme types followed by the disruptive natural selection pressure over period of time conferring adaptive fitness towards the diverse soil-climatic conditions. The predominant role of disruptive selection and introgressive hybridization in the evolution of land races of cowpea have been highlighted by Mehra, *et al.* 1970, Kohli, *et al.* 1971 and in Lablab bean by Singh & singh, 1992. Butterfly pea is a native of India where several other wild species of *Clitoria* have been reported to exist in the different warm humid regions of the country (Whyte, *et al.* 1969; Chakravarty, 1970). Wide genetic diversity in *Clitoria* genotypes within the Indian materials and in the materials from the different parts of the world have been reported by several workers (Reid & Sinclair, 1980; Anning, *et al* 1981; Singh and Singh, 1988; Singh and Gupta, 1991; Hall, 1992; Singh and Gupta,1995). Based upon the literature and examination of over 8000 herbarium vouchers a comprehensive details of phytogeographical distribution of *Clitoria* species/races alongwith their uses have been reported (Fantz, 1991) and presented in Table 1 & 2.

(B) Classification based on important agronomic characters.

Since major interest of the plant breeders has been in the identification of elite plant types with important agronomic traits, a concise key to the identification of such genotypes have been developed based on five economic traits such as;(1) plant height (cm), (2) branch number/plant, (3) dry matter yield / plant (g), (4) leaf-stem ratio and (5) protein content (%). The metrical traits (characters) graded as; (a) low, (b) medium and (c) high have been used for describing the individual varieties. The study revealed 70 different plant types. Out of

these 53 are represented by a single genotype each followed by 14 groups with two genotypes and the remaining three groups by three genotypes each (Table 13). Similar technique was also used in the classification of 370 accessions of guar *Cyamopsis tetragonoloba* (Patil, *et al.* 1983) wherein 88 divergent plant types were identified based on performance for five seed production attributes.

Hall (1992) isolated several high yielding naturalized strains of *Clitoria* in the material from the different parts of the world, and by compositing their seeds developed an improved variety known as 'Milgarra' which was released for wide scale cultivation in Queensland, Australia. Scope of study of the genetic diversity in *Clitoria* is in the identification of productive genotypes. The present study indicated that out of 92 indigenous lines eight lines namely ILCT 213, 215, 221, 249, 261, 269, 272 and 278 were outstanding in productivity and were isolated as elite selection for further studies on the germination behaviour, stability in productivity and their relative growth rates (RGR).

(C) Documentation and cataloguing

A proper characterization, cataloguing and documentation of germplasm repositories of the different crops depict the extent of genetic diversity available with the different research institutes and these informations are widely used as a reference point for the exchange and/or import of specific materials from one region of the world to another. Several such documents on various crops are being regularly published by National Bureau of Plant Genetic Resources (NBPGR) New Delhi, and the International Plant Genetic Resources Institute (IPGRI), FAO, Rome. The documents help the plant breeders in selecting suitable genotypes for use in the crop improvement programme. In the present study a detail catalogue for the genepool of *C. ternatea* has been developed for 12 characters (Table 12).

Factors influencing the germination of *Clitoria* seeds

(1) Different sowing depths (cm)

The germination behaviour in the different seed types of butterfly pea was studied under pot experiments with the different treatments of sowing depths (cm) and soil types. *Clitoria* seed germination was significantly influenced by the different sowing depths. The average germination decreased progressively from 72.5 % at 2 cm soil depth to a minimum of 35.8 % at 8 cm (Table 14). The different seed types also showed a significant differential response to the sowing depth. The maximum germination was recorded in the bluish grey coloured seeds (ILCT 221) with 91.3 % at 2 cm depth, grey and black seeds (ILCT 272 & 213) 73% at 4 cm depth, Black seeds (ILCT 272) 60 % at 6 cm, and grey seeds (ILCT 213) 47 % at 8 cm depth.

The genotype ILCT 221 which showed maximum germination at 2 cm depth also showed minimum germination (22.2 %) at 8 cm depth. On the other hand the brown seeded type ILCT 269 showed a near stable germination rate of 42-54 % at 2 cm to 8 cm soil depth . The grey and black seeded types maintained germination around 71-74 % at 2 cm and 4 cm soil depth followed by considerable reduction in germination with further increase in the depth of sowing. But it is only the grey coloured seed type which has consistently maintained a relatively higher germination rate as compared to all other types at more than 2 cm sowing depth (Table 14). Result showed that a sowing depth of 2-4 cm was ideal for seed germination of all the seed types. It is reported that besides moisture and temperature the presence of about 20% Oxygen and 0.03 % Carbon dioxide in atmospheric air is most suitable for germination of any seed (Mayer and Poljakoff-Mayer, 1982). In many wild/range species the seeds are naturally dispersed on the soil surface where they get partially or entirely covered with the leaf litter. After the onset of summer rains the seeds lying on the soil surface show prolific germination unlike those seeds which lie deeper in soil (Kinzel 1926). This implies that there is a specific need of air, temperature and moisture for most of the wild species which is usually available within a few cm of the soil depth. In case of deep sown seeds the impaired seed biochemistry, mainly due to the reduced oxygen concentration and increased carbon dioxide adversely affect the seed germination (Mayer and Poljakoff- Mayber, 1982). Effect of sowing depth on the seed germination of the different *Stylosanthes* species (Stonard, 1969; Rai, 1990) was almost the same as has been observed for *Clitoria* in the present studies.

(2) Different soil types and their combination

Germination of the different seed types was significantly influenced by the variation in soil types. Amongst the soil types studied mixed type of soil was most conducive to seed germination (73 %) followed by organic soil, red soil and the least (58 %) in the black soils (Table 15). The seed germination was maximum for the grey seeded ILCT 213, brown seeded ILCT 261 and black seeded ILCT 278 in mixed soil, black seeded ILCT 272 in organic soil.

Physical properties such as soil structure, water holding capacity, hydraulic conductivity, water osmolarity, ionic strength and aeration of the soil appear to play a major role in seed germination (Hadas, 1977; Hadas and Russoo, 1974; Collis-George and Hector, 1966). While the mixed soil types were most congenial for seed germination on account of favorable soil properties, other soil types such organic soils suffered from poor moisture retention and poor seed soil contact, black soils suffered from poor aeration, excess soil compactness and soil moisture.

(3) Different temperature treatments

The effect of different temperature treatments (tested in BOD incubator) on the germinability of different seed types in *Clitoria* was significant. Out of four temperature treatments the most conducive to seed germination was 35°C closely followed by 25°C and minimum at the lowest temperature 5°C. The germinability of the seeds progressively increased from 68-72 % with increase in temperature from 15-35° C (Table 16). The optimal temperature requirement for the maximum seed germination varied significantly with the different kinds of seeds. Lowest effect of temperature was noted for brown seeded type ILCT 261. In four seed types germination percentage was almost similar for all the temperatures above 15°C, and in the remaining there was a progressive increase in the germination with the increase in the temperature. It is reported that high temperatures cause eruption in the striophiolar plug of the seed which facilitate optimal entry of water into the seeds and thereby increasing its permeability (Dell, 1980). With increased permeability for moisture the seed germination is activated (Mayer and Poljakoff-Mayber, 1982; Mullick and Chatterji, 1967; Chatterji, 1966).

(4) Different treatments of light colours

The effect of illuminated light of different colours on the germination of different types of butterfly pea seeds was studied. The colour illumination treatments comprised blue, violet, red and total darkness. The effect of different light colours on seed germination was significant on the different types of the seed. While maximum germination in six out of eight seed types was observed in the total darkness, violet colour was preferred by grey seeded ILCT 215, red colour by bluish grey seeded ILCT 249 and brown seeded ILCT 269. The colour of light had no effect on the seed germinability in the brown seeded ILCT 261 (Table 17). Illumination of the leguminous seeds to red / orange light has been reported to stimulate germination but on the contrast blue light is reported to inhibit the germination (Evanari *et al.*, 1957).

The present studies indicated that germination of the different types of *Clitoria* seeds have a different genotypic response to the various treatments of sowing depth, soil types, temperature and the colour of light illumination. Previous studies indicate that the germination behaviour of the different leguminous seeds, within or between the different species, is a genetically controlled character which reflects as differential behaviour to seed dormancy, hard seededness and polymorphism (Esashi and Leopold, 1968; Chatterji, 1966; Mullick and Chatterji, 1967). Besides this, the seed germination trends may be considerably different for the laboratory test, pot experiments and actual field conditions.

Genotypic stability

The genotypic X environment interaction for the agronomic traits show the degree of consistency (stability) in the performance of genotypes over a range of environments. A highly stable genotype with high yield potential is, therefore, a prerequisite for the release of a cultivar for wide scale cultivation. The components of the stability are; the varietal means and the general mean of all the varieties for each location; Linear regression (bi) of the varietal means with the general mean for each location, and deviation from the regression for each variety (S^2di). Considerable wealth of information on the components of stability have been provided by several authors and the most effective one has been indicated by Finlay and Wilkinson (1963). He considered linear regression slopes as a measure of stability. Eberhart and Russel, 1966 emphasized the need of considering both linear (bi) and non-linear (S^2di) component of genotype X environment interaction to judge the stability of the cultivar. However, Breese, 1969; Samuel, *et al.* 1970; Paroda and Hayes, 1971; Jatasra and Paroda, 1979; Dangi, *et al.* 1994; Henary, 1995; Lodhi and Sangwan, 1996 were of the opinion that the linear regression may simply be regarded as a measure of response of particular genotype over a range of growing environments, whereas the deviation around the regression (S^2di) are a better measure of stability. The genotype with the lowest standard deviation is the most stable type and *vice-versa.*

The significant variances were observed for dry fodder yield (DFY t/h), crude protein yield (CPY t/h) and seed yield (t/h) in *Clitoria* genotypes. All these characters along with green fodder yield (GFY t/h) also showed significant linear environmental effect, but variety X environment effects were significant only for dry matter yield (t/h) and crude protein (t/h) yield (Table 18). The varietal differences for plant height, branch number/plant, GFY/plant, DMY/plant and leaf-stem ratio were not significant. The environmental influence both linear as well as non linear and variety X environment interaction effects on all these characters were highly significant (Table 18). *Clitoria* shows indeterminate vegetative (trailing type) growth and there is no clear cut difference between the vegetative and reproductive growth phases. Vegetative growth in fodder legumes with trailing growth habit such as cowpea and field bean are predominantly influenced by the environmental effects rather than genetic effects (Singh and Hazra, 1987; Shukla *et al.* 1993). The results indicated that only two characters namely DMY (t/h) and CPY (t/h), for which the varietal differences as well as variety X environment effects were significant, appeared to be most important for the stability analysis of the genotypes. Out of eight genotypes only two namely IICT 249 and IICT 278 had very high mean dry fodder and crude protein yield; and with regression coefficient in the range of 1.08 to 1.46 along with insignificant standard deviation qualify to be the most stable variety (Table 19). The crude protein in the leguminous crops have been reported to be controlled by a major gene (Shukla *et al* .1993).

Relative growth rate (RGR)

Relative growth rate (RGR) is an index of the plant's potential to accumulate dry matter over a given period of time. An aggressive growth form is the preferred type for mix crop situation where the legume is to compete for the available resources of moisture, nutrients and light. The RGR studies were conducted on eight elite selections of *Clitoria* at two stages of growth, *i.e.*, 40-60 days and 50-60 days. The result of the study indicated considerable variation in the whole plant growth rate and the growth of its components such as leaf and stem at both the stages of plant growth (Table 20). During the first growth phase (40-50 days) the stem part of the plant showed almost twice as much RGR as the leaf component but at the later stages the differences narrowed down. In general the RGR of the whole plant and its component was considerably reduced with age of the plants. The results indicate that high RGR at the first stage of plant growth was accompanied by a relatively higher leaf/stem ratio than at the later stages of growth (Table 21). It is evident from Table 22 that the leaf/stem ratio is a strongly associated character with the RGR of the stem component at both the stages of plant growth. While the RGR values of the whole plant and its components were strongly associated amongst themselves within each growth phase, the same RGR values were strongly and negatively associated with their respective dry matter yield preceding to the respective growth phases (Table 22). Plants with low initial dry matter yield tended to grow more aggressively than the ones with high initial dry matter yield. Under sole crop situations branches of the *Clitoria* plants intertwine with each other resulting in considerable self shading effects and consequent loss of sun light utilization in photosynthesis. Self shading effects at the later stages of the plant growth may also be one of the reasons of reduced RGR values of the plants and its components. The results indicated that the selection for aggressive growth types could be based on high leafiness of the plants. Very high values of coefficient of variation for each RGR value at both the phases of plant growth indicate ample scope of selection of aggressive growth types in *Clitoria*. This legume by virtue of its fast growth habit and trailing nature has been recommended for mix cropping with tall growing grasses for increasing the nutritional value of the mixed swards (Crowder 1974; Singh and Singh 1988).

Grass-legume compatibility and productivity

The productivity of the grasslands is dominated by a few native grass species such as *Sehima, Dichanthium, Cenchrus, Heteropogon, Chrysopogon, Themeda, Iseilema* etc. (Dabadghao and Shankarnarayan, 1973). These native grasses are characteristically low in protein content and their total dry matter digestibility is also very poor. Unfortunately, protein rich legume species are represented in very low number and their contribution to the overall productivity of the grassland is also meagre. The chemical fertilizers besides being costly are

also environmentally hazardous if used on a large scale in the native grasslands. The cheapest way to improve forage quality and productivity , world over, has been through an extensive use of productive forage legumes in the native grassland (Donald, 1963; Patil and Kanodia, 1977; Shankarnarayan, *et al.* 1975; Velayudhan *et al.* 1977 & 1979; Chauhan and Faroda, 1979; Kanodia, 1984; Dwivedi, *et al.*1991; Trinbath, 1974 ;Bhana and Millar, 1978). The legumes not only fix considerable amount of atmospheric nitrogen into the soil but also improve the soil structure, organic carbon, phosphorous and moisture retention capacity (Singh, 1988 ; Hazra, 1988 and 1993; King, *et al.*1965). The ability to fix atmospheric nitrogen and organic carbon to the soil varies from one species to other. The main beneficiaries of legume mediated nitrogen fixation are the companion crops of cereals/grasses which are known to be heavy consumers of nitrogen. Amongst the indigenous legumes *Clitoria ternatea*, a productive pasture legume, have shown wide range of adaptability and persistency in arid to warm-humid areas of the country (Whyte, *et al.* ,1969; Chakravarty, 1970; Singh and Singh, 1988; Singh and Gupta, 1991). Introduction of *Clitoria* in *Cenchrus* based pasture significantly increased total nutrient out turn as compared to *Cenchrus* alone (Velayudhan, *et.al*. 1976).

This legume has not been exploited in this country to any appreciable extent for upgrading the productivity of the native pastures. One of the main reason is an absence of relevant information on its production behaviour under mix crop situation against the different native grasses.

The results of various grass-legume combination treatments involving three native grasses viz. *Chrysopogon fulvus, Heteropogon contortus* and *Cenchrus ciliaris* and two legumes viz. *Clitoria ternatea* and *Leucaena leucocephalla* (subabul) have been reported in the present study.

Dry matter (biomass) and crude protein yield

When *Clitoria* was intercropped with subabul the mixed crop yield increased to 5.8 t/h DMY and 1.137 CP yield (t/h) from the pure crop *Clitoria* yield of 2.59 t/h DMY and 0.51 t/h CP yield, registering a net gain of 124 % for DMY and 121 % for CP yield. The studies indicated (Table 26) that the most beneficial combination in terms of crude protein yield was *Clitoria* + *Subabul* (CPY 1.137 t/h) followed by three species combination, *Clitoria* + *Cenchrus* + *Subabul*, (CPY 1.114 t/h). The later combination also had the highest DMY amongst all the treatments (9.75 t/h).

Under the sole crop situation all the grass species except *Heteropogon* produced significantly higher biomass than *Clitoria*. Amongst the grasses *Cenchrus* produced maximum CPY (0.329 t/h) followed by *Chrysopogon* (0.295 t/h) and *Heteropogon* (0.133 t/h). The percentage CP in the forage was maximum for *Clitoria* (19.7 %) followed by *Cenchrus* (7.4

%), *Chrysopogon* (5.7 %) and lowest for *Heteropogon* (4.6 %). As a result of very high crude protein content of *Clitoria* forage its CP yield in the pure stand was significantly higher (0.51 t/h) than the grasses (0.133-0.329 t/h) despite the fact that its DMY was much lower than most of the grasses (Table 28).

The legume *Clitoria* as a companion crop of the grasses helped to increase the DMY of the mixture (*Clitoria* + grass) by a margin of 8 % to 40 % over the sole stand of the grass and 47 % to 140 % over the sole stand of *Clitoria* pure (Table 29). In terms of CP yield the only beneficial combination was *Clitoria* + *Cenchrus* where a gain of 17.6 % CPY over the pure stand of *Clitoria* was obtained. The grass *Heteropogon* despite being the lowest producer of DM and CP yield in pure stand was most benefited by its association with *Clitoria*. As compared to the pure stand of the grass, the grass + *Clitoria* combination registered a net gain of 174 % CPY in *Heteropogon*, 73 % in *Chrysopogon* and 82 % in *Cenchrus* (Table 30). In all the combination treatments of grass + *Clitoria* the proportion of the grass component in the total DM and CP yield of the mixture was 52 to 67 % for DM and 30 to 51 % CPY.

All the combinations of the Subabul with the different grasses produced 31 to 63 % more DMY and 36 to 77 % more CPY as compared to *Clitoria* + grass combinations. The grass + Subabul mix crop yield registered an increase of 71 % to 113 % in DMY and 150 % to 384 % CP yield over the pure crop of the grass . In all the combinations of grass + Subabul the proportion of the grass component to the total DMY and CPY of the mixture was 43 to 60 % for DMY and 20 to 41 % for CP. Amongst the grasses *Heteropogon* contributed relatively less to the total biomass (52 % & 43%) than other grasses - legume combinations (Table 29).

On the other hand Subabul combinations with the grass resulted in an increase of 26 to 73 % CPY and the *Clitoria* + Subabul + grass 69 to 118 % over the pure crop of *Clitoria*. As compared to the pure crop of the grasses the CP yield of the *Clitoria* + grass plots increased by a margin of 73 to 174 % , Subabul + grass 150 to 300 % and *Clitoria* + Subabul + grass 215 to 548 % (Table 30).

When two legumes Viz. *Clitoria* and Subabul were mix cropped together with the different grass species the percentage increase in yield of the mixture was 159 % to 276 % in DM and 69 to 118 % CP yield over the sole crop of *Clitoria* and 68 % to 131 % DM and 205 to 548 % CP yield over the sole crop of the grass species. The three species combinations also resulted in an increase of 54 to 76 % DMY and 76 to 137 % CPY over *Clitoria* + grass (Table 29 & 30).

The positive response of the grass-legume combinations over the pure stands of the grass component increased progressively over the years. The average productivity of biomass from the grass-legume mixture increased from 4.60 t/h in the establishment year to 7.72 t/h in

the third year of growth, an increase of 68%. This benefit in yield potential is perhaps due to the significant increase in fodder yielding attributes mainly number of tillers/branches and plant height in component species (mostly in grasses). Stimulation of legumes on biomass production of grass components might be due to its active participation in tiller development and tussucks growth (Frey and Maldonado, 1967). All the legumes measured to fix atmospheric nitrogen in the soils at one hand and its potential availability to grass component on the other hand (Dwivedi *et al.* 1988). This system might be evident with the present study for biomass production.

When *Clitoria* and Subabul together were intercropped with different grasses the relative contribution of the different components to the total biomass ranged from 20 to 27% for *Clitoria*, 34 to 45% for Subabul and 28 to 46% for the grasses.

The result is of considerable significance because it reveals special adaptation/preference of the fast trailing legume *Clitoria* for the tree legume Subabul. In natural pasture conditions infested with wild bushes *Clitoria* may be the ideal legume forming a thick canopy of its trailing branches over the shorter growing bushes/trees which could easily be browsed by all types of wild and domesticated animals.

One of the characteristic feature of all the grass-legume mixture is that the companion grasses are enriched by higher protein content in the forage at the expense of the legume components. Protein enrichment of grass through the association of legume was inversely related to the inherent value of the grass proteins under sole crop situations. The percentage proportion of protein in the *Clitoria* forage was reduced from a level of 19.69% as a pure crop to a level of 14 to 16.6% when intercropped with the different grasses. The crude protein content of the grass species increased from sole crop situation to crop mix situation with the different legumes. This increase was from 5.7 to 6.1% in *Chrysopogon*, 4.57 to 5.32% in *Heteropogon* and 7.4 to 7.6% in *Cenchrus*.

Effect of different interactions on dry matter and crude protein content of *Clitoria ternatea*

In all the three years of the study the first cut yield of *Clitoria* in all the treatments was significantly higher than the second cut yield (Tables 31-34). The first cut yield of the *Clitoria* and the mean yield of all the years was significantly higher in the pure stand and in combination with subabul than in any other grass-legume combination treatments.

Environment in the different years had a profound effect on the dry matter yield (t/h) and its crude protein content (%) in *Clitoria*. The dry matter and crude protein content in

forage decreased progressively, often significantly, from first year to the third year of growth. Only in case of *Clitoria* + *Cenchrus* + Subabul treatment there was a significant improvement in the crude protein content of the *Clitoria* forage from the first year to the third year of growth (Tables 35-38).

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SUMMARY

The legume *Clitoria ternatea* L. commonly known as butterfly pea is indigenous to India where it is adapted throughout the tropical regions in the rain fall range of 500 to 1500 mm. It is a perennial pasture legume highly productive during the rainy season. Its potential has not yet been fully exploited for upgrading the productivity and the nutritional value of the native pastures. One of the main reason is a general lack of relevant information on the various aspects such as the extent of genetic diversity in the indigenous genotypes, factors related to its establishment in the pasture and its production behaviour under sole and mix crop situations against the different native grasses.

The present study was therefore carried out to (i) Assess the genetic diversity present in the germplasm collected from different parts of the country as well as characterization and cataloguing. (ii) Factors affecting the establishment of *Clitoria ternatea* in pastures viz. effect of various factors such as sowing depth, soil types, temperature and light colours on the germination of polymorphic seeds. (iii) Assessment of variability in important forage yielding attributes. (iv) Genotypic stability and (v) Compatibility of *Clitoria* with native grasses and tree component and its effect on quality and productivity.

The basic material of the present study comprises of 92 germplasm collected from major areas of its distribution such as Rajasthan, Uttar Pradesh, Delhi State, Madhya Pradesh, Gujrat, Maharashtra, Tamil Nadu, Bihar and West Bengal. For the study of genetic diversity all the *Clitoria ternatea* genotypes were grown in replicated trial and the data on various plant attributes and productivity was recorded for three consecutive years at the peak period of the plant growth, *i.e.* at 50% flowering stage.

The seed of the *Clitoria* genotypes collected from the different parts of the country manifested considerable diversity in the seed coat colour patterns. The basic seed coat colours in *Clitoria* comprised of various shades of light brown to black colour and the different patterns developed through a uniform sprinkling of fine dots or speckles of various colour and sizes over the basic seed coat colour. The grey speckled seed coat colour types occurred most frequently followed by shining black and dark brown types with or without dottings or speckling.

Clitoria is a profusely flowering plant and the flower petals (wing, keel and standard) particularly its wings conspicuously showed various colours. The deep blue colour was the most frequent followed by white or various shades of pink against white or light blue.

Under climatic conditions at Jhansi the flowering response of *Clitoria* genotypes was day neutral. Both vegetative and reproductive growth phases continued simultaneously till late September, afterwards the growth activity progressively ceased with the increase in self defoliation and pods bearing by the end of November. A majority of the genotypes flowered in the medium range (43-46 days) followed by late and early flowering types. Due to day neutral behaviour of *Clitoria* plants the discernible genotypic coefficient of variations in flowering were rather low.

Clitoria plants being a creeper show indeterminate growth and the growth occurs from the growing tips of the main stem and the auxiliary branches. Significant differences among the genotypes were observed for all the ten characters in each individual year of the study. The genetic diversity 'amongst the genotypes was widest for green fodder yield followed by leaf number / plant and was comparatively low for branch number/plant and days to flower. The genotypes showed medium genetic diversity for the characters of elongation such as plant height and length of the branch.

The important forage yielding attribute in *Clitoria ternatea* is the leafiness as determined by leaf number / plant and the leaf/stem ratio in the forage yield along with branch number and branch length. The studies reveal that there is considerable amount of genetic diversity in these forage yielding attributes and there is wide scope for selecting high forage yielding types in *Clitoria* on the basis of profuse leafiness and branching attributes.

The results indicated that the pure stands of *Clitoria* plants in the establishment year had the highest leaf/stem ratio and the longest branch as compared to its regrowth performance in the following years. The second year of regrowth was characterized by an overall increase in size of the plants including branching behaviour, leafiness and maximum realization of yield potential, (both GFY and DMY) as compared to any other year of growth. The aggressive vigour of the *Clitoria* plants in the second year appears to be linked with the maximum foliage entailing largest surface area available for photosynthetic activity. The unique feature of the *Clitoria* plant in pure stand is that its protein content continues to increase from the first year to the third year of growth.

The classification of the *Clitoria* genotypes in the present study was based on the index score method developed by Anderson (1957). The sum of the indices for all the 10 characters provided a multi-character expression data for each genotype separately. Based on the total index values the genotypes were classified into 15 divergent groups irrespective of their geographical origin, indicating thereby existence of considerable genetic diversity within the

major geographical areas of distribution of *Clitoria ternatea* in this country. The group of genotypes with low total index values were the less vigorous growth types than those with higher values. A majority of the genotypes were represented in the high and very high index score groups. One of the important factor in the creation of considerable amount of genetic diversity in the localised populations is the prevalence of occasional out crossing which create an spectrum of segregating progenies over the generations. When these segregating populations are subject to long term natural selection pressure the result is the evolution of extremely divergent growth forms along with several intermediate growth forms. Presence of divergent growth forms in the materials from the same region may as well indicate that the different plant types may have occurred due to an exchange of genetic material at different periods between the different regions.

Since, major interest of the plant breeders lies in the identification of elite plant types with important agronomic traits, a concise key to the identification of such genotypes have been developed based on five economic traits such as plant height, branch number /plant, dry matter yield / plant, leaf-stem ratio and protein contents (%). The study revealed 70 different plant type groups, of which 53 were represented by a single genotype each followed by 14 groups with two genotypes and the remaining three groups by three genotypes each. The technique helped in identifying eight elite lines with the most favoured combination of high grades of all the five economic traits.

A proper characterization, cataloging and documentation of germplasm in the *Clitoria ternatea* based on twelve morphological traits have been prepared to depict the extent of genetic diversity available within the indigenous material. This catalogue would be useful as a ready reference to the researchers and help them to identify suitable types for use in the crop improvement programmes.

Differential response of various treatments viz. sowing depth, soil types, temperature and colour of light illumination was observed on germination of different category of *Clitoria* seeds. It infers that different groups of *Clitoria* seeds have genetic differences among themselves. The seed germination decreased progressively from a maximum at 2 cm soil depth to a minimum at 8 cm. The different seed types had a differential response to the sowing depth, but the types showing maximum germination at shallow depth were the most adversely affected at greater depth of sowing. Amongst the soil types studied mixed type of soil was most conducive to seed germination followed by organic soil, red soil and the least in the black soils.

The studies indicated that for *Clitoria* seed germination 35°C was most conducive closely followed by 25°C and minimum at the lowest temperature 5°C. The optimal temperature requirement for the maximum seed germination varied significantly with the different kinds of

seeds. Lowest effect of temperature was noted for brown seeded type ILCT 261.

The effect of different colours of light on seed germination was significant on the different types of the seed. While maximum germination in six out of eight seed types was observed in the total darkness, next in promoting germinability was violet colour for grey seeded, red colour for bluish grey and brown seeded types.

A highly stable genotype with high yield potential is a prerequisite for the release of a cultivar for wide scale cultivation. In the present study the stability analysis on eight selected genotypes was made using Eberhart and Russel (1966) model. The components of the stability worked out are; the varietal means and the general mean of all the varieties for each location; Linear regression (bi) of the varietal means with the general mean for each location, and deviation from the regression for each variety (S^2 di). The varietal differences due to *Clitoria* genotypes were significant for dry fodder yield (DFY t/h), crude protein yield (CPY t/h) and seed yield (t/h). All these characters along with green fodder yield (GFY t/h) also showed significant linear environmental effect, indicating a favourable response of environment on the expression of these traits. A significant effect of the variety *X* environment on the dry matter yield (t/h), crude protein (t/h) yield and leaf/stem ratio also indicated differential response of the varieties to environment on the expression of these traits. The varietal differences for plant height, branch number/plant, GFY/plant and leaf-stem ratio was not significant. The environmental influence both linear and non linear as well as variety *X* environment interaction effects on all these characters were highly significant. These studies suggest that the forage attributes in the species *Clitoria ternatea* which shows indeterminate vegetative (trailing type) growth with no clear cut difference between the vegetative and reproductive growth phases are predominantly influenced by the environmental effects rather than by genetic effect. The results indicated that only two characters namely DMY (t/h) and CPY (t/h), for which the varietal differences as well as variety *X* environment effects were significant, appeared to be the most important for the stability analysis of the genotypes. Out of eight genotypes only two namely IICT 249 and IICT 278 had very high mean dry fodder and crude protein yield; and with regression coefficient in the range of 1.08- 1.46 alongwith insignificant standard deviation qualify to be the most stable variety.

Relative growth rate (RGR) is an index of the plant's potential to accumulate dry matter over a given period of time. An aggressive growth form is the preferred type for mix crop situation where the legume is to compete for the available resources of moisture, nutrients and light. The RGR studies were conducted on eight elite selections of *Clitoria* at two stages of growth, *i.e*, 40-50 days and 51-60 days. The result indicated considerable genotypic variation in the whole plant growth rate and the growth of its components such as leaf and stem at both the stages of plant growth. During the first growth phase (40-50 days) the stem part of the

plant showed almost twice as much RGR as the leaf component, but at the later stages such differences were not as much clearly marked. In general the RGR of the whole plant and its components was considerably reduced with age of the plants. The results indicated that high RGR at the first stage of plant growth was accompanied by a relatively higher leaf/stem ratio than at the later stages of growth. The leaf/stem ratio was strongly associated character with the RGR of the stem component at both the stages of plant growth. Plants with low initial dry matter yield tended to grow more aggressively than the ones with high initial dry matter yield. The results indicated that the selection for aggressive growth types could be based on high leafiness of the plants. Very high values of coefficient of variation for each RGR value at both the phases of plant growth indicated ample scope of selection of aggressive growth types in *Clitoria*. This legume by virtue of its fast growth habit and trailing nature could be recommended for mix cropping with tall growing grasses for increasing the nutritional value of the mixed swards.

The results of various grass-legume combination treatments on productivity and nutritional quality involving three native grasses viz. *Chrysopogon fulvus, Heteropogon contortus* and *Cenchrus ciliaris* and two legumes viz. *Clitoria ternatea* and *Leucaena leucocephalla* (subabul) have been reported in the present study.

Under the sole crop situation all the grass species except *Heteropogon* produced significantly higher dry matter yield than *Clitoria*. The percentage CP in the *Clitoria* forage (19.7 %) was nearly three times to that of the grasses (4.6 - 7.4 %). As a result of very high crude protein content of *Clitoria* forage its CP yield in the pure stand was also significantly higher than the grasses. Amongst the grasses *Cenchrus* as a sole crop produced maximum CPY followed by *Chrysopogon* and *Heteropogon*.

The legume *Clitoria* as a companion crop of the grasses helped to increase the dry matter and crude protein yield of the mixture (*Clitoria* + grass) by a significant margin over the sole stands and of the grass. But when compared with the CPY of the pure crop of *Clitoria* the only beneficial combination was *Clitoria* + *Cenchrus* where a gain of 17.6 % CPY was obtained. The grass *Heteropogon* despite being the lowest producer of DM and CP yield in pure stand was most benefitted by its association with *Clitoria*.

All the combinations of the Subabul with the different grasses produced significantly higher DMY and CPY as compared to the pure crop of the grasses and also to all the *Clitoria* + grass combinations. When two legumes Viz. *Clitoria* and Subabul together were mix cropped with the different grass species the percentage increase in yield of the mixture was 159 % to 276 % in DM and 69 to 118 % CP yield over the sole crop of *Clitoria* and 68 % to 131 % DM and 205 to 548 % CP yield over the sole crop of the grass species. The three species combinations

also resulted in an increase of 54 to 76 % DMY and 76 to 137 % CPY over *Clitoria* + grass. As compared to the pure crop of the grasses the CP yield of the *Clitoria* + grass plots increased by a margin of 73 to 174 %, Subabul + grass 150 to 300 %.

In all the combination treatments of grass + *Clitoria* the proportion of the grass component of the mixture was 52 to 67 % for DM and 30 to 51 % CPY. In all the combinations of grass + Subabul the proportion of the grass component to the total DMY and CPY of the mixture was 43 to 60 % for DMY and 20 to 41 % for CPY. When *Clitoria* and Subabul together were intercropped with different grasses the relative contribution of the different components to the total biomass ranged from 20 to 27 % for *Clitoria*, 34 to 45 % for Subabul and 28 to 46 % for the grasses.

The studies indicated that the most beneficial combination in terms of crude protein yield was *Clitoria* + Subabul followed by three species combination, *Clitoria* + *Cenchrus* + Subabul. The later combination also produced the highest DMY amongst all the treatments.

The positive response of the grass-legume combinations over the pure stands increase progressively over the years. The average productivity of biomass from the grass-legume mixture increased from 4.60 t/h in the establishment year to 7.72 t/h in the third year of growth, an increase of 68% .

The result is of considerable significance because it reveals special adaptation / preference of the fast trailing legume *Clitoria* for the tree legume Subabul. In natural pasture conditions infested with wild bushes *Clitoria* may be the ideal legume forming a thick canopy of its trailing branches over the shorter growing bushes/trees which could easily be browsed by all types of wild and domesticated animals.

One of the characteristic feature of all the grass-legume mixture is that the companion grasses are enriched by higher protein content in the forage at the expense of the legume components. Protein enrichment of grass through the association of legume was inversely related to the inherent value of the grass proteins under sole crop situations. The percentage proportion of protein in the *Clitoria* forage was reduced from a level of 19.69 % as a pure crop to a level of 14 to 16.6 % when intercropped with the different grasses. The crude protein content of the grass species increased from sole crop situation to crop mix situation with the different legumes. This increase was from 5.7 to 6.1 % in *Chrysopogon*, 4.57 to 5.32 % in *Heteropogon* and 7.4 to 7.6% in *Cenchrus*.

In all the three years of the study the first cut yield of *Clitoria* in all the treatments was significantly higher than the second cut yield. The first cut yield of the *Clitoria* and the mean

yield of all the years was significantly higher in the pure stand and in combination with subabul than in any other grass - legume combination treatments.

Environment in the different years had a profound effect on the dry matter yield and its crude protein content (%) in *Clitoria*. The dry matter and crude protein content in forage decreased progressively, often significantly, from first year to the third year of growth. Only in case of *Clitoria* + *Cenchrus* + Subabul treatment there was a significant improvement in the crude protein content of the *Clitoria* forage from the first year to the third year of growth.

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* Not seen original